



NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

THESIS

**OPERATIONALLY RESPONSIVE SPACELIFT:
SUPPORTING A SEVEN-DAY LAUNCH SCHEDULE**

by

Erin T. Hearne

June 2013

Thesis Advisor:
Second Reader:

Charles M. Racoosin
Alan D. Scott

Approved for public release; distribution is unlimited

THIS PAGE INTENTIONALLY LEFT BLANK

REPORT DOCUMENTATION PAGE			<i>Form Approved OMB No. 0704-0188</i>	
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington, DC 20503.				
1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE June 2013	3. REPORT TYPE AND DATES COVERED Master's Thesis	
4. TITLE AND SUBTITLE OPERATIONALLY RESPONSIVE SPACELIFT: SUPPORTING A SEVEN-DAY LAUNCH SCHEDULE			5. FUNDING NUMBERS	
6. AUTHOR(S) Erin T. Hearne				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey, CA 93943-5000			8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING /MONITORING AGENCY NAME(S) AND ADDRESS(ES) N/A			10. SPONSORING/MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government. IRB Protocol number _____.				
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution is unlimited			12b. DISTRIBUTION CODE A	
13. ABSTRACT (maximum 200 words) In 2001, the Air Force issued AFSPC 001-01, <i>Mission Need Statement for Operationally Responsive Spacelift</i> , identifying the need for a responsive launch system ready to launch and reach orbit within hours of call-up to deploy space assets in support of military operations. Current range operations include months and often years of pre-launch planning and infrastructure development in order to meet launch vehicle, customer, and safety constraints. This thesis studies the Air Force's limited ability to support small satellite launches into sun-synchronous low earth orbit in response to a Tier-2 ORS request, focusing on launching from a single range with two different small payload launch vehicles and investigates the potential for making spacelift more responsive. This investigation determined that the Air Force is not currently capable of launching either vehicle type within a seven day schedule due to a variety of doctrinal, procedural, and resource challenges and restrictions. This thesis presents several suggested changes and risk mitigation options for overcoming these shortfalls in equipment, personnel, and paperwork to increase the responsiveness of spacelift in support of the Air Force and DoD launch objectives.				
14. SUBJECT TERMS Operationally Responsive Space			15. NUMBER OF PAGES 81	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT UU	

THIS PAGE INTENTIONALLY LEFT BLANK

Approved for public release; distribution is unlimited

**OPERATIONALLY RESPONSIVE SPACELIFT:
SUPPORTING A SEVEN-DAY LAUNCH SCHEDULE**

Erin T. Hearne
Captain, United States Air Force
B.S., U.S. Air Force Academy, 2005

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN SPACE SYSTEMS OPERATIONS

from the

**NAVAL POSTGRADUATE SCHOOL
June 2013**

Author: Erin T. Hearne

Approved by: Charles M. Racoosin
Thesis Advisor

Alan D. Scott
Second Reader

Rudy Panholzer
Chair, Space Systems Academic Group

THIS PAGE INTENTIONALLY LEFT BLANK

ABSTRACT

In 2001, the Air Force issued *AFSPC 001-01, Mission Need Statement for Operationally Responsive Spacelift*, identifying the need for a responsive launch system ready to launch and reach orbit within hours of call-up to deploy space assets in support of military operations. Current range operations include months and often years of pre-launch planning and infrastructure development in order to meet launch vehicle, customer, and safety constraints. This thesis studies the Air Force's limited ability to support small satellite launches into sun-synchronous low earth orbit in response to a Tier-2 ORS request, focusing on launching from a single range with two different small payload launch vehicles and investigates the potential for making spacelift more responsive. This investigation determined that the Air Force is not currently capable of launching either vehicle type within a seven day schedule due to a variety of doctrinal, procedural, and resource challenges and restrictions. This thesis presents several suggested changes and risk mitigation options for overcoming these shortfalls in equipment, personnel, and paperwork to increase the responsiveness of spacelift in support of the Air Force and DoD launch objectives.

THIS PAGE INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

I.	THESIS INTRODUCTION	1
A.	BACKGROUND	2
B.	PURPOSE.....	3
C.	RESEARCH QUESTIONS.....	4
D.	BENEFITS OF STUDY.....	4
E.	SCOPE AND METHODOLOGY	5
II.	OPERATIONALLY RESPONSIVE SPACE	7
A.	INTRODUCTION.....	7
B.	LAUNCH OPERATIONS.....	7
1.	Western Range Overview	7
2.	Requirements.....	9
C.	DOCTRINE AND OPERATING INSTRUCTION REVIEW	9
1.	Air Force Doctrine	9
2.	DoD Instructions	10
3.	Range Commanders Council	11
4.	Air Force Instructions	11
D.	CHAPTER SUMMARY.....	15
III.	CURRENT CAPABILITIES	17
A.	INTRODUCTION.....	17
B.	LAUNCH VEHICLE OVERVIEW	17
1.	Pegasus XL	17
2.	Minotaur I.....	18
C.	LAUNCH DIRECTIVES AND OTHER DOCUMENTATION	19
1.	UDS Requirements.....	19
2.	Readiness Reviews and Go/No-Go Criteria.....	21
3.	Range Safety Operations Requirements (RSOR)	24
D.	KEY MISSION EVENTS.....	26
1.	Scheduling.....	26
2.	Integration	27
3.	Installation	27
4.	Safety Checkout	27
5.	Instrumentation Checkout	28
E.	LAUNCH VEHICLE AND RANGE OPERATIONS CREWMEMBERS	28
1.	Training	28
2.	Readiness	30
F.	CHAPTER SUMMARY.....	31
IV.	RESEARCH ANALYSIS AND APPLICATION OF STUDY	33
A.	INTRODUCTION.....	33
B.	RELEVANT LAUNCH HISTORY.....	33
1.	Pegasus AIM.....	33

2.	Minotaur I NROL-66.....	36
3.	Minotaur I TacSat-2 Mission.....	38
C.	SUPPORTABLE LAUNCH SCHEDULE.....	39
1.	Minotaur I.....	39
2.	Pegasus.....	42
D.	PRE-LAUNCH REQUIREMENTS.....	42
1.	ORS Tier-2 Launch Profile.....	42
2.	Crew Readiness.....	43
3.	Documentation.....	44
E.	LIMITING FACTORS.....	44
F.	CURRENT STATE OF OPERATIONALLY RESPONSIVE SPACELIFT.....	46
1.	Improving Spacelift Responsiveness.....	46
2.	Concept Validation.....	50
G.	CHAPTER SUMMARY.....	51
V.	CONCLUSIONS.....	53
A.	KEY POINTS AND RECOMMENDATIONS.....	53
1.	Equipment.....	53
2.	Personnel.....	54
3.	Administrative.....	54
B.	AREAS TO CONDUCT FURTHER RESEARCH.....	55
	LIST OF REFERENCES.....	57
	INITIAL DISTRIBUTION LIST.....	63

LIST OF FIGURES

Figure 1.	Orbit Inclinations and Launch Azimuths Available from the Western Range (From Wertz and Larson, 734)	8
Figure 2.	Universal Documentation System Flow (From “Western Range User Handbook” 2–3).....	20
Figure 3.	Typical Pegasus Integration and Test Schedule (From “Pegasus User’s Guide” 48).....	34
Figure 4.	Timing of Processes from Spacecraft Mate Through Launch – Minotaur (From Schoneman, Amorosi and Laidley 9).....	38

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF TABLES

Table 1.	Tiered Approach to Enhance Responsiveness of Space Capabilities (After National Security Space Office)	2
Table 2.	Data Requirements Documentation Lead Times (From <i>Air Force Space Command Manual 91-710, Volume 2, 10</i>).....	14
Table 3.	Pegasus AIM Launch Vehicle Processing Timeline (After Kennedy Media Gallery)	35
Table 4.	Pegasus AIM Major Range Operations (After Buchholz 1).....	36
Table 5.	Minotaur I NROL-66 Major Range Operations (After Buchholz 1)	37
Table 6.	Minotaur I Estimated Current ORS Capability.....	40
Table 7.	Pegasus Estimated Current ORS Capability	41

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF ACRONYMS AND ABBREVIATIONS

ACO	Aerospace Control Officer
AFB	Air Force Base
AFDD	Air Force Doctrine Document
AFI	Air Force Instruction
AFPD	Air Force Policy Directive
AFSPC	Air Force Space Command
AIM	Aeronomy of Ice in the Mesosphere
BMC	Basic Mission Capable
BOA	Broad Ocean Area
C&L	Capabilities and Limitations
CMR	Combat Mission Ready
COTS	Commercial Off-the-Shelf
CT	Command Transmitter
DoD	Department of Defense
DoDD	Department of Defense Directive
EAL	Entry Access List
FFPA	Final Flight Plan Approval
FTS	Flight Termination System
GRR	Group Readiness Review
ICBM	Intercontinental Ballistic Missile
ILL	Impact Limit Lines
JFC	Joint Forces Commander
LDA	Launch Decision Authority
LRR	Launch Readiness Review
LSE	Launch Support Equipment
LST	Launch Safety Team
LV	Launch Vehicle
LWO	Launch Weather Officer
MD	Mission Director
MDR	Mission Dress Rehearsal
MFCO	Mission Flight Control Officer
MRTFB	Major Range and Test Facility Base
NASA	National Aeronautics and Space Administration
NOAA	National Oceanic and Atmospheric Administration
NRO	National Reconnaissance Organization
OCA	Orbital Carrier Aircraft
OD	Operations Directive
OG	Operations Group
OR	Operations Requirements

ORS	Operationally Responsive Space
PFPA	Preliminary Flight Plan Approval
PL	Public Law
RCO	Range Control Officer
ROC	Range Operations Commander
ROPS	Range Operations Squadron
RRR	Range Readiness Review
RSOR	Range Safety Operations Requirements
SLC	Space Launch Complex
SLM	Space Launch Manifest
SMC	Space and Missile Systems Center
SW	Space Wing
UDS	Universal Documentation System
USAF	United States Air Force
VAFB	Vandenberg Air Force Base
VPS	Vehicle Peculiar Supplement
WR	Western Range
WROCI	Western Range Operations, Communications & Information Services

ACKNOWLEDGMENTS

First and foremost, I would like to thank my family for encouraging me to write and complete this thesis. Special thanks to Mr. Ed Buchholz and Mr. Joe Nemeth, both government servants at Vandenberg AFB, for being willing to dig up range operations documents that were not available on the Internet and were invaluable to my research. The following individuals were willing to read and offer their suggestions, including my advisors, Professor Charles Racoosin and Professor Alan Scott, and my patient friends, Ms. Morgan Gabse, Mrs. Sarah Nemeth, and Captain Jennifer Azzarello. Most importantly, I need to thank my husband, Chris, who encouraged me through my two deployments and all three of his, patiently reminding me to keep working on this paper and reminding me how happy I would be when I finished. He was, of course, absolutely correct.

THIS PAGE INTENTIONALLY LEFT BLANK

I. THESIS INTRODUCTION

In 2001, the Air Force issued *AFSPC 001-01 Mission Needs Statement for Operationally Responsive Spacelift*. It identifies the need for a responsive launch system, “ready to launch within hours of call-up, and to conduct military operations within hours of reaching orbit. Spacelift, and the supported space assets, must be able to quickly respond to a dynamic threat environment, changing mission requirements, and increased operational tempos and utilization rates.” Since that time, the Air Force has retired the Department of Defense (DoD)-owned Titan launch vehicle, thus limiting domestic launch options to commercial vehicles purchased from United Launch Alliance, Orbital Sciences Corporation, SpaceX. Additionally, considerable downsizing of supporting instrumentation sites has occurred on both major launch ranges (Vandenberg Air Force Base (AFB) and Cape Canaveral Air Force Station), limiting each range’s ability to support more than one operation at any time.

Current range operations (specifically pre-launch activities that include the use of range instrumentation and personnel) average one month of mission preparation prior to launch. This estimate does not include the months and often years of pre-launch planning, infrastructure development, payload processing and testing, and booster delivery and pad setup that have to be accomplished in order to meet launch vehicle, customer, and safety constraints. This thesis will investigate the apparent trend toward unresponsiveness and evaluate the current ability and shortcomings of meeting an aggressive seven day launch schedule in support of urgent needs requests from theater operations commanders.

This thesis will focus on the Air Force’s ability to support small satellite launches into sun-synchronous low earth orbit in response to an Operationally Responsive Space (ORS) request, but will focus on launching from a single range, Vandenberg AFB, which is the Air Force’s primary launch site for sun-synchronous orbits. Additionally, only two launch vehicles will be considered: Orbital Science Corporation’s air launched Pegasus and ground launched Minotaur vehicles. Other sites that support high inclination launches for Minotaur and Pegasus vehicles include Wallops, Kodiak, and Kwajalein, however these will not be addressed in order to refine the scope of this thesis.

A. BACKGROUND

As the world advances further into the space age, the path to ensuring space superiority is changing. No longer is it feasible to dominate space and support the warfighter solely through conventional long-term acquisition programs utilizing the launch-on-schedule method. Recent budget cuts to key space programs like the National Aeronautics and Space Administration (NASA) and the National Oceanic and Atmospheric Administration (NOAA) mean a significant reduction in long-term acquisition programs and a critical need for more affordable and responsive space assets (King 2012, n.p.). ORS and the launch-on-demand method is one proposed approach to ensure continued access to space as well as meet the immediate needs of the commanders on the ground.

Tier-1	Tier-2	Tier-3
-Rapidly exploit existing on-orbit capabilities	-Replenish and augment with <i>existing</i> technologies and capabilities	-Replenish and augment with <i>newly developed</i> technologies and capabilities
-Timeline: Hours to Days	-Timeline: Days to Weeks	-Timeline: Months to 1 Year

Table 1. Tiered Approach to Enhance Responsiveness of Space Capabilities (After National Security Space Office)

The Air Force's ORS Office established definitions for three tiers of responsiveness. Tier-1 uses existing and on-station assets to meet a specific need. Many of these satellites would be multipurpose, allowing prepositioning of assets that share cost with other missions and tasks. The timeline for getting a Tier-1 asset online and ready to use is defined as immediate within hours or days. If no on-orbit capabilities exist that meet the Joint Force Commander's (JFC) need, the next option is to use a launch ready asset. Tier-2 uses Commercial-Off-The-Shelf (COTS) and pre-developed standby satellites to rapidly deploy a needed capability. To ensure maximum readiness, both satellites and launch vehicles need to be launch ready prior to the need arising. The

timeline for delivering a Tier-2 asset into orbit and ready to use is defined as days to weeks.

Finally, Tier-3 assets utilize rapid acquisition methods to develop, test, and deploy a new satellite capability. Unlike standard space acquisition programs that can take years, the timeline for developing, deploying, and activating a Tier-3 asset is months to one year (National Security Space Office 2007, 4). On June 29, 2011, the Defense Department's ORS Office successfully launched the ORS-1 satellite. The objective was to design, develop, and deploy the ORS-1 satellite in 24 months; the project ultimately took 30 months. While this is distant from the 12 month vision, it was extremely impressive and considered very successful compared to the standard space acquisition timeline (Ledbetter 2012, n.p.).

B. PURPOSE

There are a lot of fundamental problems facing the ORS Office and Tier-2 launches. "Even for small satellites, the satellite build cycle (1–3 years), launch vehicle build cycle (12–18 months), range safety and operations (up to 18 months for Eastern and Western Ranges), launch site operations (30 days), and on-orbit checkout (weeks) all require a lengthy timeline" (Kim and McLeod 2010, 90). To make this program feasible, it must be assumed that the build cycles for both the satellite and the launch vehicle have been completed in advance. In order to make the ORS concept work, as much preparation as possible will have to already be completed before the ORS need arises. Pre-approvals through advance planning are critical.

This thesis will look at the feasibility of ORS from a launch perspective, specifically the feasibility of launching a field-ready Tier-2 satellite within a seven day timeline, consistent with the "days to weeks" laid out by the ORS Office. Current launch operations require at least thirty days from arrival of the booster on-site to the actual launch; clearly this pace is not sufficient to meet the needs of ORS. This research will be used to recommend changes in architecture and doctrine in order to meet the proposed seven day launch schedule.

C. RESEARCH QUESTIONS

This thesis will address three specific questions to gauge current capabilities and future potential for operationally responsive spacelift.

What is the shortest launch schedule that can currently be supported?

This question will evaluate the current capabilities of the Pegasus and Minotaur I vehicles to respond to a rapid launch request assuming that all tasks that can be accomplished prior to launch date selection have been accomplished and using historical launch information as a baseline.

What are the primary obstacles to achieving a seven day launch schedule?

This question will assess administrative, operational, and support tasks that currently prevent or have the potential to interrupt a seven day launch schedule.

What changes can be made to reduce the time required from the initial request for an ORS response to launch?

This question will address mitigation techniques to increase the responsiveness of spacelift operations, including tasks that can be accomplished in advance, opportunities for standardization to reduce workload and increase personnel proficiency, and other administrative changes to the way launch operations are performed.

D. BENEFITS OF STUDY

Operationally responsive space is still a hot topic among space professionals, however the majority of the discussion revolves around the spacecraft, with little attention given to the launch vehicles and ranges that must provide on-demand launch support. This thesis will identify significant issues that must be addressed in order to successfully execute short notice launches. It will also highlight potential areas of improvement to minimize the time from initial ORS request to on-orbit support, which is critical to the dynamic environment in which today's military operates.

E. SCOPE AND METHODOLOGY

This thesis will focus on the Air Force's ability to support small satellite launches into sun-synchronous low earth orbit in response to an ORS request from a single range, Vandenberg AFB is the Air Force's primary launch site for sun-synchronous orbits and will be the range studied in this paper. Additionally, only two launch vehicles will be considered: Orbital Science Corporation's air launched Pegasus and ground launched Minotaur vehicles. The primary assumptions are that the satellite is ready to be delivered with all pre-integration testing (including but not limited to vibration and acoustic shock testing, vacuum and thermal testing, and subsystem testing) previously completed and that a launch vehicle is immediately available. Additionally, the seven day timeline will not include on-orbit checkout. This paper assumes that there is value in the responsive launch of small payloads, regardless of whether that is a tactical or strategic value. There is some debate in the space community about the battlefield utility of a responsive and tactical class of satellite, specifically whether or not the physical constraints of low earth orbit can meet the operational requirements of a tactical mission; this is beyond scope of this thesis and remains a topic for further study (Tomme 2006).

THIS PAGE INTENTIONALLY LEFT BLANK

II. OPERATIONALLY RESPONSIVE SPACE

A. INTRODUCTION

The Air Force and the DoD are developing the concept of ORS as the future of military space operations. This “launch-on-demand” model is a departure from current launch-on-schedule doctrine. To meet the accelerated launch schedule required to support ORS, the Air Force must adapt launch range operations and spacelift doctrine.

The objective of ORS is to rapidly deploy a space asset at the request of commanders on the ground to provide space support at the tactical level. It is designed to provide “the responsive and affordable delivery of space assets in hours-to-days instead of weeks-to-months” (Noel, Escorpizo, and Jones 2004, 7). Currently, launch schedules begin years out, with the majority of the operational requirements in writing at least 90 days prior to the first pre-launch operation (“Western Range User Handbook” 2009, 2-4). A typical launch will begin pre-launch operations around 30 days before launch, with complex missions and new launch vehicles beginning even sooner. The launch-on-schedule model will continue to be relevant for large satellites and conventional space acquisitions, however significant changes will have to be made to the launch ranges in order to accommodate a launch-on-demand architecture.

B. LAUNCH OPERATIONS

1. Western Range Overview

The Western Range (WR), located at Vandenberg AFB, CA, is the DoD’s West Coast launch and test range, supporting polar orbit spacelift launches, Intercontinental Ballistic Missile (ICBM) test launches, and missile defense testing. “The WR provides metric tracking, telemetry acquisition, short and long range photo optics, command control, meteorological forecast and real-time observation, area surveillance, communications, real-time data processing and post-flight data production” (“Western Range User Handbook” 2009, 1-1). Range instrumentation consists of telemetry acquisition and processing systems, metric and Global Positioning System (GPS) tracking antenna and radars, airspace and ocean surveillance systems, safety command

control systems, meteorological sensors, and communication systems. The 30 Space Wing (SW) manages the WR; their mission statement is “To provide combat capability to the joint warfighter through assured access to space and combat ready airmen” (Vandenberg Air Force Base - Home 2012).

The unique geography at Vandenberg AFB allows rockets to launch due south without flying over land until reaching Antarctica, minimizing the risk of spent rocket stages or failed rockets from impacting inhabited land areas. Vandenberg is the choice location for launching reconnaissance and Earth observation satellites that require polar orbits (Day n.d., n.p.). The WR is capable of supporting launch azimuths between 140 and 201 degrees, as displayed in Figure 1. Since the first launch in 1958, Thor, Atlas, Titan, Scout, Athena, Delta, Taurus, Pegasus, and Minotaur family space launch vehicles have successfully taken off from the WR.

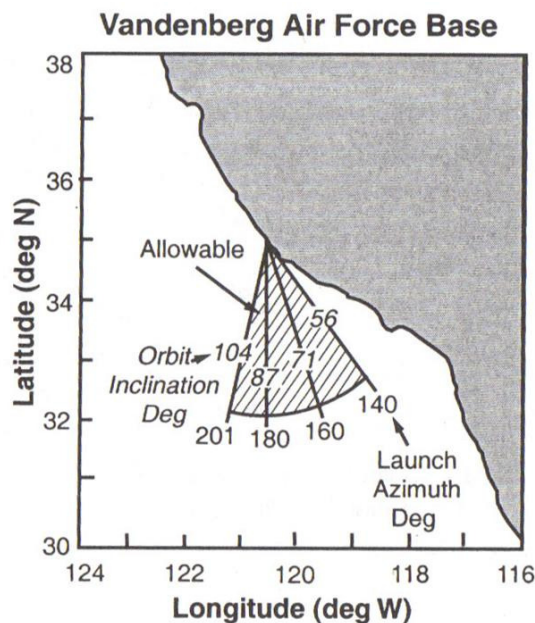


Figure 1. Orbit Inclinations and Launch Azimuths Available from the Western Range (From Wertz and Larson, 734)

All range operations are conducted in the Western Range Operations Control Center (WROCC). The WROCC is designed to be able to conduct two separate launch

activities simultaneously, however this capability has not been utilized for real world operations. Frequency protection is always a necessity during launch operations in order to protect both the launch vehicle and the payload; the WR's Frequency Control and Analysis System maintains an interference-free radio frequency (RF) environment to protect launch vehicles, payloads, and personnel ("Western Range User Handbook" 2009, 4-24). This would be a major concern during dual launch operations, as frequencies would have to be assigned in a manner that ensured the frequencies from each operation could not interfere with each other.

2. Requirements

Radar and telemetry sites must be available to provide real time telemetry and vehicle health and status during flight. Command transmitters must have line of sight of the vehicle from launch until Safety End of Mission to ensure that destruct commands can be transmitted to the vehicle if any safety rules are violated. Depending on the launch trajectory, local and remote radar, telemetry, and command transmitter sites might be mandatory. All communication nets and data links must be functioning during launch operations. Additionally, in order to launch safely, each vehicle has specific weather constraints that cannot be violated. These requirements will be further discussed in the next chapter.

C. DOCTRINE AND OPERATING INSTRUCTION REVIEW

1. Air Force Doctrine

According to *Air Force Doctrine Document (AFDD) 2-2*, Space Operations, satellite deployment launch operations are currently conducted using the launch-on-schedule approach, with launches planned in advance and executed in accordance with a standing launch schedule. *AFDD 1*, Air Force Basic Doctrine, states that, "Due to requirements to ensure spacelift availability for all U.S. users, the Air Force conducts launch operations based on a launch-on-schedule approach. All users are scheduled for spacelift based on priority as well as launch vehicle and payload readiness. Changes to published schedules require the formal coordination and approval from all parties

affected, or preemption of the existing schedule by the Secretary of Defense” (*Air Force Doctrine Document 1* 2003, 52).

The concept of launch-on-demand is briefly defined in *AFDD 1*, but is not currently in use. “This approach provides an alternative means of spacelift whereby launches may occur when required to accommodate user needs. Launch-on-demand dictates spacelift capability must be obtained in advance of specific requirements” (*Air Force Doctrine Document 1* 2003, 53). An estimated 9% of satellites fail during their operational lives (Long, Richards, and Hastings 2007); even for cases where a satellite fails well before its projected end-of-life date, the Air Force has primarily followed the launch-on-schedule model, occasionally advancing the launch schedule by a couple of months, but overall not significantly changing the original schedule. In order to meet ORS requirements, the AF would have to further develop the existing but limited launch-on-demand doctrine to address concerns like prioritization and timelines for launch operations.

2. DoD Instructions

Department of Defense Directive 3200.11, Major Range and Test Facility Base (MRTFB), defines roles and responsibilities for DoD leadership components and bases identified as MRTFBs. The directive establishes policy that, “The MRTFB may be used by other DoD users (including DoD training users), and by users outside the Department such as U.S. Government Agencies, State and local governments, allied foreign governments, and commercial entities.” Additionally, the directive states, “Scheduling of the MRTFB shall be based upon a priority system that gives equitable consideration to all DoD Components and accommodates DoD acquisition program priorities” (*Department of Defense Directive 3200.11* 2007, 3). Launch-on-demand operations could be considered a priority; however, there will be political considerations for deconfliction with scheduled Missile Defense Agency (MDA), National Reconnaissance Office (NRO), foreign allies, and high-value commercial launches.

DoD 3200.11-D, Major Range and Test Facility Base Summary of Capabilities, provides a brief description of all DoD major test activities identified in *DoDD 3200.11*

(*Department of Defense Directive 3200.11-D* 1983). The summary states that the WR can support spacelift and ICBM launches across a wide range of launch azimuths and allows for direct polar insertion without flying over any populated areas. In addition to space and missile field test operations, the WR also supports a variety of aeronautical tests in the West Coast Offshore Operating Area (WCOOA). All launch operations must be deconflicted with scheduled aeronautical tests to ensure instrumentation is available and frequency protection is maintained.

3. Range Commanders Council

The Range Commanders Council (RCC) was established in 1951 to consolidate and standardize “the technical and operational needs of U.S. test, training, and operational ranges” (Range Commander's Council 2012). The council includes military test and launch ranges for the Army, Navy, and Air Force, as well as civilian ranges operated by NASA. The RCC provides a way for DoD test ranges to communicate and discuss common problems. The *RCC Standard 321-10*, Common Risk Criteria for National Test Ranges, defines consensus standards for the range risk management process and risk criteria. The companion document, *RCC 321-10 Supplement*, provides additional detailed information to assist in the implementation of standards in the basic document (O'Connor 2010, 15).

4. Air Force Instructions

Air Force Policy Directive (AFPD) 10-12, Space, identifies the Air Force as the DoD executive agent for space launch, responsible for launching satellites for the DoD and other government agencies for required orbital operations. *Air Force Instruction (AFI) 10-1211*, Space Launch Operations, implements *AFPD 10-12*. The instruction states that, “AFSPC’s spacelift mission is to ensure successful delivery of space systems to support national objectives and provide a decisive advantage to U.S. forces worldwide” (*Air Force Instruction 10-1211* 2006, 2).

Consistent with *DoDD 3200.11*, the instruction states that the Space Wing Commander must, “Operate the range as part of the DoD MRTFB by providing government facilities and range services to all authorized users.” *AFI 10-1211* supports

the concept of ORS through the policy of assured access to space. “United States Government space policies identify “assured access to space” as the need to guarantee the availability of critical space capabilities for executing space missions” (*Air Force Instruction 10-1211* 2006, 1). Additionally, the instruction briefly addresses schedule execution as being a priority based launch queue. This is consistent with the needs of changing to a launch-on-demand architecture, with rapid launches holding a higher national priority and mission priority—and therefore a higher launch priority—than routine commercial, civil, and DoD payloads.

AFSPCI 10-1208, Spacelift Operations, establishes Air Force Space Command’s roles and responsibilities relating to launch operations. Similar to the Air Force level instruction, *AFSPCI 10-1208* further supports the policy of assured access: “Assured mission capability for critical space systems can be achieved only through assured and protected access to space” (*Air Force Space Command Instruction 10-1208* 2011, 4). Assured access is a critical component of the ORS construct. The instruction also considers both launch-on-schedule and launch-on-demand strategies. “Space lift is a key enabler that establishes and supports a broad range of space capabilities. Space lift includes two complementary strategies: current routine launch operations and future responsive launch operations. The U.S. uses routine launches to populate satellite constellations on a scheduled basis and will develop responsive launch operations, or on-demand launch capabilities, to support more time-critical space support operations” (*Air Force Space Command Instruction 10-1208* 2011, 4). This would support future implementation of ORS with minimal change to the instruction.

While the instruction supports both rapid and long term launch schedules, it does dictate that launch operations must be done in a cost-effective manner. “AFSPC must maintain a successful, robust, secure, and modern space lift capability to meet war fighter and other national security mission needs. All echelons within AFSPC must strive to meet this basic requirement at an affordable cost” (*Air Force Space Command Instruction 10-1208* 2011, 8). Maintaining a reasonable price tag while accelerating what is normally a one- to two-year process down to a single week will inevitably prove challenging, especially in an extremely budget-constrained environment.

Finally, the instruction directs the Space Wing Commander to conduct a final, mandatory Launch Readiness Review (LRR) prior to each operation. An LRR is described as an, ..".Assessment of both the ability to meet the mission design requirements and the current launch schedule based on the sum of flight worthiness and flight readiness" (*Air Force Space Command Instruction 10-1208* 2011, 41). The Space Wing Commander chairs the review, which is attended by the Mission Director, the Operations Group Commander, the Chief of Wing Safety, the Mission Support Group Commander, Western Range Operations, Communications & Information Services (WROCI) Contractor Representative, and the applicable launch vehicle and payload representatives. The LRR is normally conducted the day prior to launch and covers launch personnel, a brief mission description, an overview of all significant scheduled events and their status, launch facility, vehicle and upper stage status, satellite/payload status, day of launch weather forecast, range support status, communication network support, safety and contingency response support, a summary of significant events in the launch countdown, any open items that may impact the launch, and a final go/no-go readiness poll.

AFSPC Manual 91-710, Range Safety User Requirements, volumes one through seven, define the Range Safety Program for all AFSPC launch activities. "These activities include the life cycle of launch vehicles and payloads from design concept, test, checkout, assembly, and launch to orbital insertion or impact" (*Air Force Space Command Manual 91-710*, Volume 1, 2004). The manual also establishes and enforces range safety requirements, ensuring that an acceptable level of safety is provided throughout all pre-launch, launch, and post-launch operations. Risk management is performed for three safety categories—public, launch area, and launch complex safety.

Volume two discusses flight safety requirements, including flight plan approval and data delivery times. Range customers must provide a flight plan with the anticipated trajectories so Range Safety analysts can validate the flight plan does not violate any safety margins, overland restrictions, or impact restrictions. Preliminary flight plan approval is due one year prior to the scheduled launch. Final flight plan approval is due 60 days prior to launch. Range customers only need to supply required data once if no

changes occur from operation to operation, for example if the flight plan is identical to a previous launch (*Air Force Space Command Manual 91-710, Volume 2, 2004, 10–12*). Table 2 shows the requirements for new and established launch vehicles.

Vehicle/Missile	Lead Time Before Launch (Calendar Days) New/Existing
Ballistic Missile	
Preliminary Flight Plan Approval (PFPA)	2Y/1Y
Final Flight Plan Approval (FFPA)	120D/60D
Space Vehicle: Single Flight Azimuth	
PFPA	2Y/1Y
FFPA	120D/60D
Project Firing Tables	7D
Space Vehicle: Variable Flight Azimuth	
PFPA	2Y/1Y
FFPA	12M/6M
Project Firing Tables	45D

Table 2. Data Requirements Documentation Lead Times (From *Air Force Space Command Manual 91-710, Volume 2, 10*)

AFSPC Manual 91-711, Launch Safety Requirements for Air Force Space Command Organizations, provides the policy and requirements needed for AFSPC organizations to meet the Launch Safety Program mission. “The Launch Safety mission is to protect the public, launch base personnel (government and contractor), range infrastructure, and third party personnel from the hazards associated with AFSPC range operations. Launch Safety is a function performed by the Wing Safety organization at AFSPC ranges and includes: Systems Safety, Pad Safety, Flight Analysis, and support to Flight Operations” (*Air Force Space Command Manual 91-711 2007, 5*). The manual provides guidance for risk assessment for all phases of the launch operation. Each risk is assessed individually, and the assessed risks are summed up to provide an overall operational risk. Risks evaluated include, but are not limited to, toxic hazards, overflight, overpressure, and debris hazards.

D. CHAPTER SUMMARY

Any future sun-synchronous mission launch out of the WR will have to continue to adhere to these Air Force, DoD, and RCC regulations, most importantly the required major operations and safety milestones. Adhering to them by the letter while executing a launch-on-demand mission may prove challenging. Several of these documents may need to be modified to reflect the increasingly responsive nature of the spacelift mission without sacrificing public safety or ignoring political considerations and implications. In an increasingly budget restricted Air Force, it is reasonable to expect further downsizing of already limited range resources, which will drive further need to modifications to how the WR operates and how doctrine and instructions regulate those operations.

THIS PAGE INTENTIONALLY LEFT BLANK

III. CURRENT CAPABILITIES

A. INTRODUCTION

Currently the WR focuses on supporting launch-on-schedule operations. All facets of launch preparation are well suited to support operations with one to two years of notice. The lengthy schedules allow for sufficient time to deconflict between different range customers, flex with launch delays, and train personnel for unique mission events, new vehicles, or complicated payload preparation. Orbital Sciences Corporation has developed a family of small launch vehicles intended to reduce cost and schedule, while still fitting into the launch-on-schedule paradigm.

B. LAUNCH VEHICLE OVERVIEW

1. Pegasus XL

The Pegasus XL is a winged, three-stage, solid rocket booster that is launched from an L-1011 aircraft from approximately 39,000 ft (11,887 m) at Mach 0.82 over the broad ocean area (BOA). The Pegasus is capable of launching small satellites up to 1,000 lbs (454 kg) into low earth orbit. “From the WR, Pegasus can achieve inclinations between 70° and 130°” (Pegasus User's Guide 2007, 8). Orbital has launched 41 Pegasus rockets since 1990, carrying more than 80 satellites. 36 of those launches were declared successes, including all of the last 27 launches, giving the Pegasus one of the most successful launch rates currently available (Orbital Sciences Corporation 2012).

NASA uses a launch vehicle certification process to utilize available launch technology while ensuring the risks associated with a given launch vehicle are consistent with the risk classification for the payload and mission. Certification is based on launch vehicle history, flight anomalies, mission failure resolutions, and NASA technical assessments. Three categories exist based on the level of launch vehicle risk: high (Category 1), medium (Category 2), and low (Category 3). Payloads are classified into four classes: A, B, C, and D. Class A payloads are described as having the highest value; the payloads are a high priority, national significance is considered to be high, cost is rated as high, the technology and equipment is considered to be very complex, and

mission lifetime is expected to be longer than five years. On the opposite end, Class D payloads are low priority, low national significance, low cost, medium to low complexity, and mission lifetimes are shorter than two years. Class A payloads can only be launched on Category 3 launch vehicles. The Pegasus XL is currently the only small launch vehicle to have NASA's Category 3 Certification, permitting it to launch NASA's highest valued payloads (*NASA Policy Directive 8610.7D* 2008).

The L-1011 is a low maintenance reusable launch platform; because the Pegasus is air launched, no launch pad refurbishment is required between launches. This makes the Pegasus a desirable launch vehicle for rapid successive launches. Payload support services and the Vehicle Assembly Building (VAB) are located at Vandenberg AFB, making it very easy to have vehicles on location in standby status for operationally responsive spacelift operations.

2. Minotaur I

The Minotaur I is a four-stage solid propellant ground launched vehicle, developed by Orbital for the USAF as a, "cost effective, reliable and flexible means of placing small satellites into orbit" ("Minotaur I User's Guide" 2006, 3). The Minotaur family includes four other vehicles; for the purpose of this paper, "Minotaur" refers only to the Minotaur I launch vehicle. The Minotaur is capable of accommodating orbital inclinations between 60° and 120° from VAFB and launches from Space Launch Complex-8. Inclinations below 72° require an out-of-plane dogleg which reduces the amount of mass for the given payload. The small launch vehicle is capable of launching a payload mass of up to 580 kg (1,279 lbs) to an altitude of 185 km (606,955 ft). The Minotaur launch vehicle utilizes surplus Minuteman II boosters and proven upper stages from Orbital's Taurus and Pegasus launch vehicles. "The Minotaur I Launch Support Equipment (LSE) is designed to be readily adaptable to varying launch site configurations with minimal unique infrastructure required" ("Minotaur I User's Guide" 2006, 6). The baseline Minotaur mission involves conducting payload integration and

launch operations at VAFB, while campaign missions are launched at non-VAFB locations. For the baseline mission, spacecraft prelaunch operations are also conducted at VAFB.

The lower stage Minuteman booster, referred to as the Lower Stack Assembly, is processed and prepared by Air Force and Orbital personnel. “Due to operational constraints, the Lower Stack Assembly, consisting of the Minuteman motors, is processed by the Air Force at a separate facility. After testing by Orbital, it is delivered directly to the launch pad to await the arrival of the upper stack” (“Minotaur I User’s Guide” 2006, 48). It is possible to prepare the Lower Stack Assembly in advance for standby operations, with limited checks required to keep it ready for responsive operations, however this is not the standard operating procedure.

The Minotaur has a standard mission response of 18 months. This includes vehicle preparation, payload integration, and launch operations. Orbital also advertises “responsive launch solutions” available from six months to 48 hours, however this solution has not yet been executed within the given timeframe. As of September 2011, the Minotaur I launch vehicle had conducted 10 missions with a 100% success rate, delivering 33 satellites into orbit (Orbital Sciences Corporation 2012).

C. LAUNCH DIRECTIVES AND OTHER DOCUMENTATION

1. UDS Requirements

The Universal Documentation System (UDS) involves a series of administrative submittals and responses. It is used to identify the customer’s requirements and for the range to develop operational plans to support those requirements. “The UDS is a standardized documentation system that is accepted and used at a number of MRTFBs. The UDS provides a common language and format for stating program, mission, and individual operations requirements. This system is a proven means by which the WR accepts user requirements and develops plans to operate the range” (“Western Range User Handbook” 2009, 2-1).

The UDS has two types of documents: customer-generated documents, and government-generated documents. The customer (or range user) documents identify their

mission requirements, while the government documents are a direct response to a customer document and identify how the WR will support those requirements. The documents are broken down into three levels, as shown in Figure 2. Level one includes the Program Introduction and the Statement of Capability or Support. Level one is designed to initiate program support planning, and typically begins over two years before launch. Level two includes the Program Requirements Document and Program Support Plan, documenting system level descriptions, program requirements, and an assessment of the range's ability to support. The final level consists of the Operations Requirements (OR) and Operations Directive (OD), used to plan, schedule, and execute program operations. The OR must be submitted 60 days prior to the range user's first operation requiring WR support to allow time to complete the OD. The OD consists of three sections; the first two are required to be completed no later than 30 days prior to the first pre-launch operation, and the final section no later than 30 days prior to launch. The Vehicle Peculiar Supplement (VPS) is issued after the launch OD is published and details changes to section III of the OD ("Western Range User Handbook" 2009).

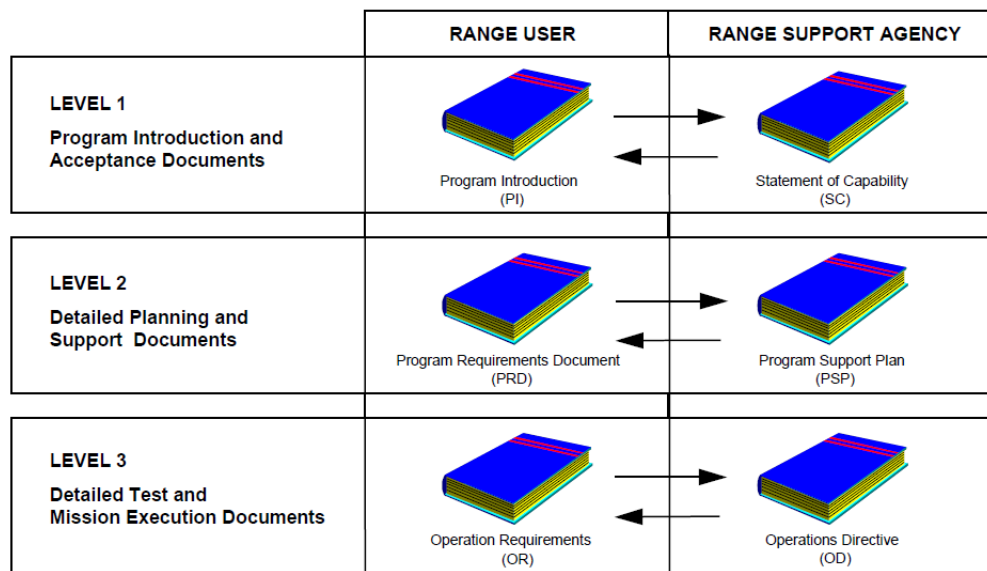


Figure 2. Universal Documentation System Flow
(From "Western Range User Handbook" 2-3)

2. Readiness Reviews and Go/No-Go Criteria

The RCC requires that a LRR be conducted for all launch operations. In addition to the LRR, the 30 SW performs two additional readiness reviews: the Range Readiness Review (RRR) and the Group Readiness Review (GRR). The RRR is briefed to the 2nd Range Operations Squadron (ROPS) commander to ensure 2 ROPS can give a go-statement at the GRR. The GRR is briefed to the 30 OG commander, and adds the weather, intel, and communication status to ensure the OG can give a go-statement at the LRR. Additionally, the wing commander has the option to direct a pre-LRR to ensure that the briefing is accurate and the briefers are prepared prior to going in front of the launch customer. The RRR and the GRR are local requirements and serve primarily as reassurance to the respective chair in preparation for the LRR. The LRR is typically conducted the day prior to launch, includes all status that is included in the GRR, and adds briefings from the payload lead, the launch vehicle team, civil engineering, base safety, and public affairs. The LRR has very specific go/no-go criteria that are mandatory prior to entering launch countdown.

a. Weather

The Vandenberg Base Weather Station operates 24 hours every day to monitor weather conditions which may impact operations and to meet the meteorological collection needs for a variety of range customers. Weather conditions that can impact launch include natural and triggered lightning, upper level winds, surface level winds that impact the toxic hazard zones, and visibility. Each vehicle has specific and unique weather constraints, supporting safety and launch agency requirements. For example, ground launch vehicles like the Minotaur I require wind data to ensure the debris ellipse does not extend over manned areas, while the air launched Pegasus will require wind data at the airfield to ensure conditions are safe for the L-1011 and any chase aircraft to take off. Weather is monitored closely starting five days prior to the scheduled launch. A forecast is briefed at the LRR, along with the probability of favorable conditions. While a launch can be scrubbed based on the forecast, typically the decision to postpone the launch until a backup date will be delayed as long as possible to maximize the chance of

launching on time while still preserving the vehicle's ability to be ready for the next approved launch window. Depending on the launch vehicle, certain events like vehicle fueling and battery activation can extend the time needed to prepare the mission for a second launch attempt beyond the earliest approved backup date.

b. Instrumentation

The Range Operations Commander briefs the status of all range instrumentation at all readiness reviews. In addition to discussing any issues that may affect a site's ability to support launch operations, all mandatory and required sites in support of safety and launch agency constraints are identified. Mandatory sites are those that can only be waived by the 30 SW Commander or the Mission Director; required sites can be waived at a lower decision level, typically the Senior Mission Flight Control Officer or the Launch Director. In the event that there is only one piece of equipment available to meet a mandatory requirement, that equipment is referred to as hard mandatory; range operators will impose a safety hold for failure of a hard mandatory item. No single point of failure will be allowed to prevent range safety personnel from maintaining positive control over a launch vehicle through the duration of the flight control mission, as there are inherent public safety implications, and likewise no single point of failure should cause range safety personnel to send destruct commands to an otherwise nominal vehicle due to inherent mission assurance implications (Range Safety Operations Requirements 2007, 20). As such, there are considerable redundant instrumentation requirements for any launch operation. The Data Control Officer summarizes the status of all communication lines supporting the operation and addresses any ongoing communication problems.

c. Safety

Flight control personnel will brief all the mandatory safety assets as well as explain the Mission Rules. The Mission Flight Control Officer (MFCO) is authorized to terminate flight of a launch vehicle when any of the following Mission Rules are violated: public endangerment, erratic performance, or unknown performance. These include, but are not limited to, failure to track the vehicle a certain time interval after

ignition, crossing destruct lines, failure to “program” (pitch downrange), or loss of all vehicle tracking data. Additionally, all hazard areas will be briefed, including land closures, railroad hold points, restricted airspace, boat exclusion areas, and any personnel evacuation or shelter in place requirements.

Prior to the LRR, safety personnel conduct the Launch Safety Team (LST) Briefing. “This briefing provides LST members and affected agencies with information regarding evacuation of safety control areas, Entry Access Lists (EALs), a chronological order for safety actions, facilities/personnel locations inside the Impact Limit Line (ILL), fire danger status, bio-environmental hazards, vehicle/payload hazards, and procedures for post-launch or abort contingencies” (*30th Space Wing Instruction 91-101* 2009, 20). The ILL extends downrange from the launch site and defines the area in which debris from planned stage drops, vehicle explosions, or thrust termination may land, and helps define the other hazard areas. Any mission unique safety requirements will be covered for each launch. Finally, the Interim Safety Board and mishap investigation authority information is discussed to prepare for potential launch mishaps.

d. Launch Vehicle and Payload Readiness

All major milestones must be completed prior to entering launch countdown. This may include, but is not limited to, payload integration, fueling operations, vehicle mating, end-to-end testing, and system checkouts. The LRR includes a general overview of the launch vehicle history and the payload’s mission.

e. Personnel Readiness

All operations and launch support personnel, including the launch vehicle personnel who work on console during launch operations, must be trained and certified in their respective positions. Additionally, all operators must be medically cleared by the Flight Medicine clinic (*Air Force Space Command Instruction 10-1202* 2008, 9). Additional personnel training requirements are at the discretion of training personnel and Air Force leadership.

3. Range Safety Operations Requirements (RSOR)

a. RSOR Overview

Public Law 81–60 states that spacelift operations can be no more dangerous than conventional airplanes flying overhead. The Western Range’s RSOR describes the necessary safety requirements for protecting the public, launch personnel, and supporting launch operations to that degree. “The mission element objective is to ensure operations result in acceptable risk to the populace and resources and do not unduly endanger successful completion of the launch mission” (Range Safety Operations Requirements 2007, 18). It is a product of the RCC’s UDS system and contains launch vehicle-specific safety information for all vehicles approved to launch on the WR. It defines key terms and lists all mandatory and required safety constraints, as well as flight readiness criteria. An RSOR Mission-Specific Supplement may be issued to update safety requirements for a specific mission that are not included in the parent document.

The RSOR mandates several pre-launch checks, including open and closed loop verification for command transmitters and automatic failover checks. The checks are conducted during Flight Termination System (FTS) end-to-end checks and again during the launch countdown. The RSOR addresses all mandatory and required constraints for safety. The difference between mandatory and required is the level of the waiver authority; mandatory constraints can only be waived by the Launch Decision Authority, while required constraints can be waived by the Chief of Safety or the Senior Mission Flight Control Officer. Some apply to all operations, while others are vehicle specific. For any launch out of the WR, clearance of all restricted areas, including within the ILL, the boat exclusion areas, and designated airspace is mandatory for safety. In order to ensure that all instrumentation sites are able to track the launch vehicle, a positive liftoff indication must be received and transmitted to initiate instrumentation sequences. All range safety weather constraints are stated within the RSOR and must be met at liftoff.

b. Pegasus Requirements

One local radar site with visibility of the drop box is mandatory for safety, with a second local site required. One local telemetry sensor and two local non-collocated

command transmitters are also mandatory for safety. There are no requirements for remote radar, telemetry, or command transmitter sites. The Pegasus is launched over the BOA, therefore no railroad hold points are needed, there are no land closures, and there is no launch support team due to the inability for debris to impact land based on the location at which the vehicle is air dropped. Surveillance of the drop box boat exclusion area is mandatory. This can be accomplished by sea craft, the Ocean Surveillance System, or by aircraft.

c. Minotaur I Requirements

One local radar site with visibility of the launch pad and one remote site are mandatory for safety, and a second local site is required. One local and one remote telemetry sensor are mandatory for safety. Two local non-collocated command transmitters and two remote transmitters are also mandatory for safety. SLC-8 requires railroad protection for approximately 14 miles of track. Land closures, boat exclusion areas, and oil platform evacuation or sheltering are determined based on the flight azimuth and trajectory of the vehicle and where stage separations occur.

d. Documentation Review and Briefings

Several reviews and briefings must occur prior to the final readiness review. The Network Implementation Plan Review ensures that all personnel work stations have the required communications. This review typically occurs around 30 days out, but can be done closer to launch if needed. It is not unusual for the plan to be revised after a dress rehearsal if a previously unknown communication need is identified. All personnel who will be sitting on console for launch are required to attend. The Instrumentation Support Briefing reviews all the instrumentation that will be supporting an operation, consistent with the approved OD. This briefing occurs shortly after the final launch OD is published, typically one to two weeks prior to launch. The LST brief is also held between one and two weeks before launch, and is discussed further later on in this chapter.

D. KEY MISSION EVENTS

1. Scheduling

There are two types of pre-launch events, and each is scheduled somewhat differently. Internal pre-launch activities are scheduled by the launch agency. Those activities do not require outside support and can proceed at whatever pace the launch agency has the personnel and equipment to support. Any activity that involves base personnel, equipment, or hazardous operations is scheduled and managed by 2 ROPS scheduling office. AFSPC maintains a 48-month launch schedule called the Space Launch Manifest (SLM). The SLM is reviewed quarterly, and primarily follows launch-on-schedule doctrine. As a result, the WR launch schedule generally operates on a first-come first-serve basis. Launches are forecasted 3 to 11 years prior to launch depending on the payload, user requirements, budget constraints, and national priorities. AFSPC reserves the right to direct mission de-stacking operations to allow another mission to move forward to launch in the interest of national priorities (*Air Force Space Command Instruction 10-1213* 2012, 17).

Additional support requests are based on range priorities and resource availability. “Launch, major launch milestone tests, critical maintenance activities and pre-launch calibration (L-1 day) checks normally will be assigned the highest priority followed by other range activities; to include preventative maintenance and periodic depot maintenance” (*30th Space Wing Instruction 13-203* 2011, 5).

Approved launch dates and associated critical milestones already on the schedule almost always receive priority over new launch requests. 2 ROPS scheduling requires requests for major pre-launch activities to be submitted at least 30 calendar days in advance in order to allow time to deconflict other scheduled operations. Minor activities can be scheduled as late as one week in advance. Due to budget constraints and a heavy reliance on contractor support, the WR operates a 40-hour work week. Special coordination and approval is required for overtime support.

2. Integration

The first major phase of ground and launch processing is launch vehicle integration. The Pegasus vehicle and the upper stage of the Minotaur I are horizontally assembled and fully tested at the Orbital integration site at VAFB. The vehicle integration and test process ensures all components and subsystems are thoroughly tested.

The second major phase is payload processing and integration. Initial payload preparation and checkout are typically performed by payload personnel. Once the payload has checked out, it is mated with the launch vehicle. All interfaces are verified and tested after final connections are made. For the Minotaur I, final integration of the upper stage and the Minuteman II booster are conducted at the pad.

3. Installation

Aircraft mating for the Pegasus vehicle typically takes place about 3 to 4 days prior to launch. The interfaces between the launch vehicle, the operations consoles, and the aircraft are tested and verified before and again after mating the launch vehicle to the carrier aircraft. The Minotaur I completes the integration process at the launch pad. It is vertically stacked at the pad and final tests are completed to verify vehicle integrity.

4. Safety Checkout

The primary pre-launch safety checkout is called the FTS End-to-End Checks. These checks are performed on the FTS in final flight configuration as close to launch as possible, and must occur within 72 hours of liftoff. Launch delays or launch vehicle configuration changes can result in the end-to-end checks having to be repeated. Range equipment and transmitters must be available to support FTS checks. Using an ordnance simulator in place of the actual flight ordnance initiators, FTS checks demonstrate that the command termination systems deliver the required energy to initiate the FTS ordnance and must be conducted on all strings of the FTS system (*Range Commanders Council Document 319-10* 2010, 5-1).

5. Instrumentation Checkout

There are two critical instrumentation checkouts that occur prior to day of launch. The first is the Range Interface Test. This test verifies the vehicle to range interfaces and satisfies range safety requirements. It includes testing of all supporting radar and telemetry sites, command transmitters, all data and communication lines, liftoff indicators and distribution, countdown clocks, and status indicators.

The second checkout is the Pre-Launch Calibrations, also called L-1 Day Checks. As the name indicates, this test is typically conducted the last duty day before launch. Final instrumentation calibration checks are conducted, after which the range is locked down and no changes to launch configuration are authorized (30th *Space Wing Instruction 13-203* 2011, 6).

E. LAUNCH VEHICLE AND RANGE OPERATIONS CREWMEMBERS

1. Training

Depending on the type of launch, the composition of the launch team varies. Spacelift launch teams consist of the range operations crew, launch vehicle crew, and payload crew. Crew position titles may vary depending on which civil, military, or contractor entities are involved.

Military range personnel include the Launch Decision Authority (typically the wing commander or vice), the Operations Director (typically the OG commander or deputy), the Range Operations Commander (ROC), the Mission Flight Control Officer (MFCO), the Range Control Officer (RCO), the Aerospace Control Officer (ACO), and the Launch Weather Officer (LWO). The Senior MFCO and the Data Control Officer are typically AF civilians. These positions all must be in compliance with *AFSPCI36-2202*.

The Space and Missile Systems Center (SMC) commander appoints, trains, and certifies an Mission Director (MD) for every DoD launch of SMC-acquired launch systems and services. The NRO and other agencies appoint their own MDs for their own respective launches and have their own internal training and certification programs. Mission directors are responsible for ensuring space flight worthiness and are the lead for

the launch vehicle and payload teams. The launch vehicle lead has fleet-wide responsibility for the launch vehicle program and is trained and certified by the launch agency. They may specialize in a single vehicle or be responsible for a LV family. The satellite vehicle lead is typically the program director for the payload acquisition program. They are trained and certified by their respective program office (*Air Force Space Command Instruction 10-1208* 2011, 14). Launch rehearsals are typically used as final training and occasionally as final certification for non-range personnel.

There are three general types of rehearsals: Green Card Rehearsals, Wet Mission Dress Rehearsals (MDRs), and Dry MDRs. A Green Card Rehearsal is a communication only countdown during which “green card” inputs are injected to simulate vehicle, range, and weather status. The objective is for key members of the launch team to practice anomaly processing and resolution (Space Launch Sample Mission 1 Mission Requirements Document 2011, 16). It is not unusual for the 30 SW to conduct one or more range-only rehearsals, utilizing green cards, but only including the range operations crew. This ensures that the combat mission ready (CMR) and basic mission ready (BMR) range personnel are familiarized with all of the vehicle specific procedures without the launch agency personnel present. For many range operators, range-only rehearsals are their first time running countdown procedures for the vehicle they are preparing to launch.

MDRs are used to certify vehicle and launch procedures and typically include the entire launch team. The difference between a wet and dry dress rehearsal is that during a dry dress rehearsal, the vehicle is powered down, while during a wet dress rehearsal all flight systems are powered. Depending on the number of pre-launch operations and the complexity of the mission, the launch agency can elect to forgo a Dry MDR and only do a single Wet MDR. It is also not unusual to have multiple dry and wet rehearsals for unusually complex operations, inexperienced crews, or new procedures.

The WR averages approximately 12 launches per year for various launch vehicles and payloads. Over a three to four year tour, a military range operator may work anywhere from three to twelve launches. As such, the level of experience for a particular vehicle varies heavily from operator to operator. Training scenarios generally focus on

the vehicles that launch most often, such as the Minuteman III. Vehicles like the Pegasus and Minotaur I do not launch regularly from the WR, meaning that the number of current operators who have experience with either vehicle is very low. Several rehearsals will be necessary to familiarize crews and mitigate risk of operator error. Currently, the WR does not have set crews and operators are not trained for specific vehicles. Depending on the level of experience for a particular crew, 30 SW leadership may require additional range only rehearsals to prepare a crew.

2. Readiness

All CMR operators must complete an initial or upgrade evaluation, meet medical qualifications, and complete a formal certification briefing prior to being certified (*Air Force Space Command Instruction 10-1202* 2008, 8). In order to maintain currency, CMR operators must attend monthly classroom and quarterly scenario training, pass an annual evaluation, and receive training on all tasks for their crew position every 12 months. Operators who fail to maintain currency or meet medical qualifications are placed in restricted status and cannot perform crew actions (*Air Force Space Command Instruction 36-2202 Volume 1* 2010, 16).

Crews are typically forecast several months in advance of a launch, but may change multiple times prior to beginning pre-launch operations, approximately 30 days from launch. At that time operators will start to receive launch documentation and procedures and begin preparations. Operators are able to take leave on a case by case basis, permitting that there is no impact to operation support, as there is no requirement for on call status since all operations are scheduled at least a week in advance. Similar to aircrew, launch team personnel are required to take adequate crew rest prior to conducting launch operations. Crew force management personnel verify that all operators are current with their training and that they meet medical requirements prior to the LRR.

The Launch Support Team begins initial preparations approximately 45 days out. Training includes launch mishap and evacuation procedures, breathing apparatus certification, and day of launch responsibilities. Key tasks for the LST include plotting roadblock locations, determining manned support locations within the hazard area,

requesting “hold harmless” letters from any tenant organizations that may have valued assets within the hazard area, submission of the launch support plan and EAL, and the LST Brief. Team readiness is briefed 10 days prior to launch at the LST Brief and again at the LRR.

F. CHAPTER SUMMARY

Currently, the WR is more than capable of supporting launch-on-schedule operations for the Pegasus and Minotaur I vehicles. The Pegasus boasts a proven and reliable launch history, while the Minotaur is a cost effective alternative for smaller payloads. There are a lot of documentation, safety, scheduling, vehicle processing, and personnel requirements for both vehicles that have minimal impact to a launch-on-schedule operation, but could pose significant delays to a launch-on-demand program. These impacts will be examined in the next chapter.

THIS PAGE INTENTIONALLY LEFT BLANK

IV. RESEARCH ANALYSIS AND APPLICATION OF STUDY

A. INTRODUCTION

The long term vision for the ORS Office and USSTRATCOM is a responsive six day launch schedule. The TacSat-2 mission in 2006 demonstrated a limited capability to perform the final vehicle preparation activities within that six day window, however certain critical events, like range operations, crew preparation, and payload checkout were not factored in to that timeline. To determine the current supportable launch schedule, it is necessary to review the most recent launches and compare those timelines. Additionally, a significant number of assumptions must be made to begin the one week timeline at payload delivery. These assumptions pose a significant obstacle to achieving the seven day launch schedule. There are opportunities to make changes to the current processes in order to reduce the time required, all which will be addressed within this chapter.

B. RELEVANT LAUNCH HISTORY

Relevant launch history will look at the most recent Pegasus and Minotaur launches from the WR and the TacSat-2 launch from Wallops Island. The most recent WR launches provide perspective on the current pace of launch operations, establishing what the minimum achievable timeline is without addressing any of the limiting factors. The TacSat-2 mission was a demonstration of the ORS capabilities of the Minotaur I and evaluated the launch vehicle's ability to meet a condensed timeline.

1. Pegasus AIM

The most recent Pegasus launch out of Vandenberg AFB was in April 2007. The Pegasus XL Rocket successfully delivered the 200kg Aeronomy of Ice in the Mesosphere (AIM) spacecraft into a 600km sun-synchronous orbit. Figure 3 shows the typical advertised integration and test schedule for the Pegasus, beginning with motor delivery 15 months prior to launch and culminating in day of launch. This timeline is designed for the typical 24- to 30-month launch-on-schedule baseline mission cycle. Of particular

interest are events that occur after payload delivery. These are the events that cannot be accomplished prior to the ORS Tier-2 mission identification.

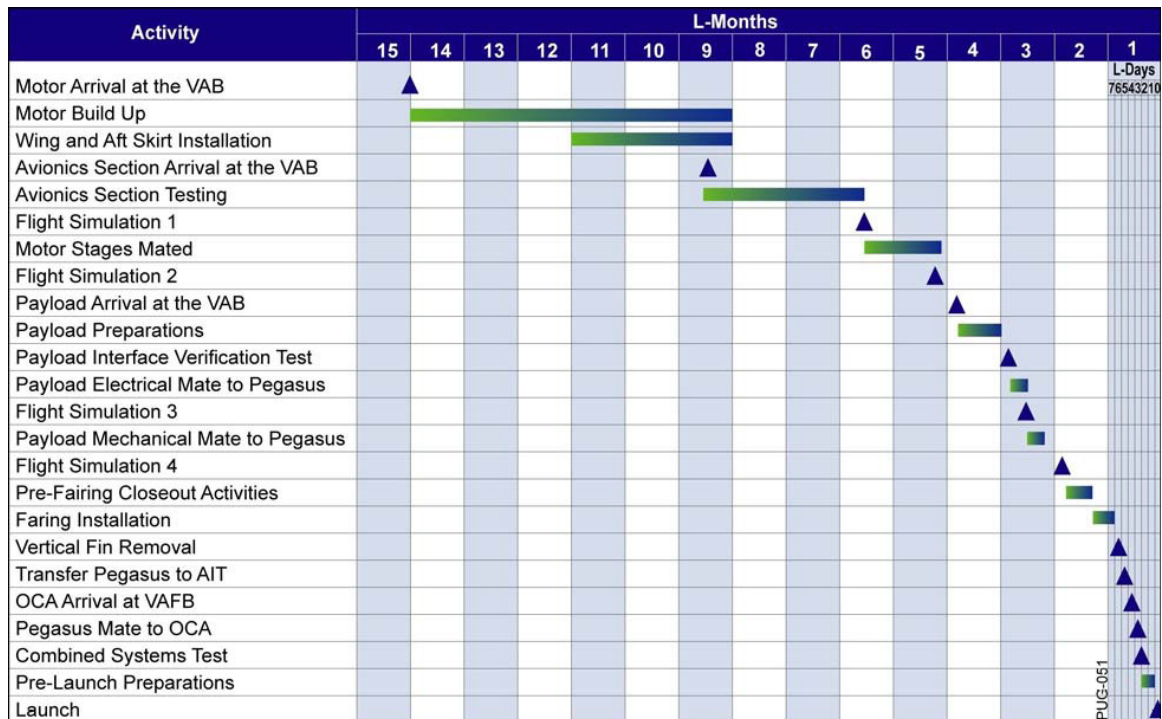


Figure 3. Typical Pegasus Integration and Test Schedule
(From “Pegasus User’s Guide” 48)

The chart shows payload arrival at four to five months prior to launch, however the “Pegasus User’s Guide” states that, “a typical Pegasus payload is delivered to the integration site at launch minus 30 calendar days.” It also allows for the majority of the last two months being allocated for pre-fairing closeout and fairing installation. This timeline is very conservative, as the actual schedule for the AIM mission demonstrates (Pegasus User's Guide 2007, 49).

Table 3 shows the actual vehicle processing timeline for the AIM mission. The AIM spacecraft arrived at Vandenberg AFB 45 days before launch. Payload integration and mating occurred 3 weeks out and fairing installation was completed less than two weeks out. All three of these significant events were well ahead of Orbital’s advertised timeline, but still shy of the desired seven day schedule. The last critical launch vehicle

processing milestone was mating the Pegasus to the L-1011 aircraft, which was accomplished three days prior to launch.

Date	Day	Event
11 Mar 07	L-45	Payload Arrival
15–16 Mar 07	L-41, 40	Payload Testing
24 Mar 07	L-32	Flight Simulation #3
24 Mar 07	L-32	Separation System to Payload Mating
27 Mar 07	L-29	Integration Testing & Flight Simulation
3 Apr 07	L-22	Payload Mating Fit Check
4 Apr 07	L-21	Payload Mating
12–13 Apr 07	L-13, 12	Fairing Installation

Table 3. Pegasus AIM Launch Vehicle Processing Timeline
(After Kennedy Media Gallery)

Section I and II and of the OR and OD were submitted and approved fall of 2004 as standard documentation for the pre-launch activity for all Pegasus launches from the WR. The mission specific OR was submitted 60 days prior to launch and the Section III Launch OD was published 30 days prior to launch. These documents identified unique requirements for the AIM payload and tasked specific range assets in support of safety and launch agency requirements. The updated countdown manual was delivered 12 days before launch and included updated procedures from recent launch activity and payload specific countdown steps.

Table 4 shows the major range operations. Range activity began 27 days prior to launch, starting with range only mission dress rehearsals. Three rehearsals were conducted due to the lack of experience of the range operations crew with the Pegasus launch vehicle and the absence of any customer requested rehearsals. The remaining major operations all occurred within six days of launch. All range activities were scheduled and completed on weekdays during normal duty hours with the exception of the two hazardous operations. Pegasus transportation and mating to the L-1011 aircraft

were conducted on a Sunday, which reduced the risk associated with transport of hazardous materials.

Date	Day	Op #	Op Title
30 Mar 07	L-26	W4124	Range-only MDR #1
6 Apr 07	L-19	W1279	Range-only MDR #2
11 Apr 07	L-14	W9866	Range-only MDR #3
19 Apr 07	L-6	W6916	Network Simulation (Rehearsal)
20 Apr 07	L-5	W6148	FTS End-To-End Test
22 Apr 07	L-3	W6936	Pegasus Transportation (HAZ)
22 Apr 07	L-3	W6944	Pegasus Mate to L-1011 (HAZ)
23 Apr 07	L-2	W6966	Combined System Test
23 Apr 07	L-2	T1460	System Validation Check
25 Apr 07	L-0	W1292	Pegasus AIM

Table 4. Pegasus AIM Major Range Operations (After Buchholz 1)

Based on the Pegasus AIM mission, the current timeline for launch vehicle processing is approximately 45 days and the timeline for major range operations is approximately 10 days. While the AIM mission was well ahead of the nominal four- to five-month schedule, there is a considerable amount of trim required to complete all activities after payload arrival within one week.

2. Minotaur I NROL-66

The most recent Minotaur I to launch from Vandenberg was in February 2011. The mission was codenamed NROL-66 and carried a classified satellite into orbit for the National Reconnaissance Office. Due to the classified nature of the payload, exact details of the payload size and final orbital characteristics were not released. The mission description stated that the satellite was launched into a polar low earth orbit.

The last Minotaur I launched from Vandenberg more than four years before NROL-66, and as a result updated pre-launch requirements were submitted as opposed to

utilizing existing documentation. The complete pre-launch and launch OR was submitted October 2010. Section I and II of the OD were published 60 days before launch and the Section III Launch OD was published 30 days before launch. The countdown manual was delivered four weeks before launch.

Table 5 shows the major range operations. The first significant range activity was a green card rehearsal, which was conducted 24 days prior to launch. The launch slipped one day due to technical issues with a range command transmitter. The second green card rehearsal and the launch were conducted on weekends. The launch window for this mission was 0400–0700 local time; all other range activities were scheduled and completed on weekdays during normal duty hours.

Date	Day	Op #	Op Title
13 Jan 11	L-22	W4940	Green Card Rehearsal #1
27 Jan 11	L-9	W2916	Range Interface Test
28 Jan 11	L-8	W8846	Range Only Rehearsal
29 Jan 11	L-7	W2922	Green Card Rehearsal #2
1 Feb 11	L-4	W2924	Mission Dress Rehearsal
2 Feb 11	L-3	W2934	FTS End-To-End Test
2 Feb 11	L-3	T9918	System Validation Check
3 Feb 11	L-2	T9894	L-1 Day Checks
5 Feb 11	L-0	W6766	Minotaur I NROL-66

Table 5. Minotaur I NROL-66 Major Range Operations (After Buchholz 1)

The typical timeline for a baseline launch-on-schedule Minotaur I mission from mission authorization to launch is 18 months. Launch vehicle integration and testing is performed between four to nine months before launch. Payload integration and launch operations are conducted in the last 30 days prior to launch.

3. Minotaur I TacSat-2 Mission

TacSat-2 launched aboard a Minotaur I rocket December 2006 from Wallops Island. The mission was sponsored by the Air Force Research Lab in support of ORS initiatives. All pre-launch activities, from payload mating to launch, were independently monitored and timed, demonstrating the responsive launch capabilities of the Minotaur I launch vehicle. The objective was to determine if the Minotaur had the capability to meet the one week call-up goal for ORS Tier II. The normal 18 month timeline was condensed down to six months from contract award to launch. “The Air Force requested that the final launch integration efforts be measured as a baseline of current integration and launch capabilities” (Schoneman et al. 2007, 8). The results indicate that final processing could be completed in a cumulative time of six days, meeting the one week requirement.

Procedure	Description	Minutes
SWP18-0006	Payload Mate	184
WP18-0030	Upper Stack Ordnance Connections	960
WP18-8030	Lower Stack Emplacement	340
WP18-9010	Thermal Cover Installation	165
AF TO	Lower Stack Transport & Tie Down	180
WP18-0041	Fairing Installation	2275
WP18-0055	Shear Pin Installation	390
WP18-0118	MMODS (FTS) Installation	1020
WP18-2401	Lower Umbilical	210
WP18-0063	Transfer Upper Stack Into T.E.	540
WP18-0061	Upper Stack Transportation	17
WP18-0062	Upper Stack Emplacement	630
WP18-8040	Rate Gyro Installation	420
WP18-2403	Post Stack Verification Test	240
WP18-2412	Range Interface Test	180
WP18-0035	FTS S/S and FCDC Connections	90
WP18-2415	FTS End to End Testing	120
WP18-0070	L-1 Closeouts	375
WP18-2507	Launch Operations	300
Total Minutes		8636
Total Hours		143.9
Total 24 Hour Days		6.00

Legend

Mechanical	Combined
Electrical	Launch Ops

Figure 4. Timing of Processes from Spacecraft Mate Through Launch – Minotaur
(From Schoneman, Amorosi and Laidley 9)

Figure 4 shows the cumulative time required to complete all vehicle processing activities. The TacSat-2 timeline began with payload mating, failing to take into account

the time required to perform spacecraft testing and final checkout prior to mating. This would only allow for a single 24 hour period to accomplish all payload checkout procedures. Due to budget constraints and the scope of the evaluation, all operations were conducted on standard single-shifts. The total time for all activities was combined, resting on the assumption that ORS launch preparation would be conducted with three shifts of crews supporting operations 24 hours a day and seven days a week. An important item to note was that the procedures were not streamlined or otherwise rehearsed in an effort to cut down the total time required, leaving room for improvement to their six day timeline.

C. SUPPORTABLE LAUNCH SCHEDULE

There have been no attempts to perform a launch-on-demand operation out of the WR, so there are some assumptions and estimates that must occur to determine what the shortest possible launch schedule is at this time. The estimates weight heavily on Orbital's findings during the TacSat-2 mission. It is assumed that the right personnel (and the right number of personnel) are available to support around-the-clock operations. Additionally, all events that can occur prior to payload delivery, including submitting all the required UDS documentation, flight plans, etc, are assumed to be complete. Failure to do so would clearly add significant length to the estimated schedules.

1. Minotaur I

Based on the recent launch history and paying particular interest in the capability demonstrated during the TacSat-2 mission, the current supportable launch schedule for the Minotaur I vehicle is still outside the one week objective. All combined range and launch agency activities would require 10 days for completion, assuming complete availability of all personnel, assets and 24-hour operations, as shown in Table 6. Values that were not measured during the TacSat-2 mission were estimated based on the completion time required for the NROL-66 mission.

Day	Event Description	Duration (hrs)
L-10	Payload Delivery	0
L-9	Payload Testing	24
L-8	Flight Simulation	6
L-8	Separation System to Payload Mating	6
L-8	Integration Testing and Flight Simulation	12
L-7	Payload Mating Fit Check	12
L-7	Payload Mating	3
L-7	<i>NIP Review</i>	0
L-7	<i>Instrumentation Brief</i>	0
L-6	Upper Stack Ordnance Connections	16
L-6	<i>Range Only Rehearsal</i>	0
L-6	Lower Stack Emplacement	5.75
L-6	Thermal Cover Installation	2.75
L-6	Lower Stack Transport & Tie Down	3
L-5	Fairing Installation	38
L-5	<i>LST Briefing</i>	0
L-4	Shear Pins Installation	6.5
L-3	MMODS (FTS) Installation	17
L-3	<i>GRR</i>	0
L-3	Lower Umbilical	3.5
L-3	Transfer Upper Stack into T.E.	9
L-3	Upper Stack Transportation	2
L-2	Upper Stack Emplacement	10.5
L-2	Rate Gyro Installation	7
L-2	Post Stack Verification Test	4
L-2	Mission Dress Rehearsal	2
L-1	Range Interface Test	3
L-1	FTS S/S and FCDC Connections	1.5
L-1	FTS End-to-End Testing	2
L-1	L-1 Closeouts	6.25
L-1	LRR	1.5
L-0	Crew Rest	12
L-0	Launch Operations	5

Table 6. Minotaur I Estimated Current ORS Capability

Durations of zero represent fixed milestones, like payload delivery, or concurrent activities, like documentation reviews, range only rehearsals, and range briefings. Payload testing and fairing installation are the most time consuming events, and as such represent the largest opportunity for process streamlining.

Day	Event Description	Duration (hrs)
L-8	Payload Delivery	0
L-7	Payload Interface Verification Testing	24
L-6	Flight Simulation	6
L-6	Separation System to Payload Mating	6
L-6	Integration Testing and Flight Simulation	12
L-5	Payload Mating Fit Check	12
L-5	Payload Mating	3
L-5	<i>NIP Review</i>	0
L-5	<i>Instrumentation Brief</i>	0
L-5	<i>Range Only Rehearsal</i>	0
L-5	Pre-Fairing Closeout Activities	3
L-4	Fairing Installation	38
L-4	<i>LST Briefing</i>	0
L-3	Vertical Fin Removal	17
L-3	<i>GRR</i>	0
L-2	Network Simulation	12
L-2	FTS End-to-End Testing	2
L-2	Pegasus Transport	6
L-2	Pegasus Mate to L-1011	6
L-2	Combined System Test	6
L-2	Mission Dress Rehearsal	2
L-1	System Validation Check	3
L-1	L-1 Closeouts	6.25
L-1	LRR	1.5
L-0	Crew Rest	12
L-0	Launch Operations	5

Table 7. Pegasus Estimated Current ORS Capability

2. Pegasus

To determine the Pegasus supportable launch schedule, the primary assumption is that there are a lot of correlations between the Pegasus vehicle and the Minotaur I. Events that took one day to complete for the AIM mission were given a value of 12 hours; those that took two days were given a value of 24 hours. This is clearly a very conservative estimate, and as such represents considerable opportunity for schedule reduction and streamlining. Based on all of these assumptions, the current supportable launch schedule for the Pegasus vehicle is just outside the one week objective. All combined range and launch agency activities would require eight days for completion, as shown in Table 7. Identical to the Minotaur I schedule, payload testing and fairing installation are again the most time consuming events. With streamlined launch vehicle preparation procedures and some of the other schedule mitigation items discussed in the following paragraphs, it is quite possible that the ambitious seven day schedule could be met for one or both vehicles.

D. PRE-LAUNCH REQUIREMENTS

1. ORS Tier-2 Launch Profile

In order to meet the high demands of a rapid response launch schedule, certain decisions need to be made well before a need is identified. The ORS Office needs to establish a standardized ORS Tier-2 launch profile; all subsequent actions are based off of that information. First, an ORS orbit (inclination and altitude) or set of orbits must be established from which Tier-2 missions can be derived from. One option is to use a parking orbit, from which a variety of operational orbits can be achieved. Additional calculations would have to be made to ensure constant launch mass as different orbits may require different amounts of onboard fuel. Another option is to utilize a single operational orbit and form a constellation of ORS Tier-2 payloads. Due to the shorter lifespan requirements of an ORS mission, this could feasibly be done without concern of deploying too many satellites into the same orbit.

Second, a fixed payload and launch mass or set of masses must be set. Limiting the number of variables is critical to ensure any payload can be loaded onto any standby

vehicle with minimal modifications to the fuel, launch profile, and safety assessments. Foremost, this simplifies the development of standardized COTS payloads that can be selected to fulfill an ORS requirement. Standardizing the payloads would also include using a common payload interface; this allows for a common procedure for payload integration, which can be rehearsed in advance, reducing the time required to complete the integration tasks. Additionally, the mass significantly impacts the flight profile and safety assessments. Using a fixed launch mass allows planners to model a single profile that can be applied to all ORS Tier-2 launches, minimizing the number of unique items for each launch, which simplifies training, preparation, and day of launch activities. In accordance with *AFSPC Manual 91-710*, identical flight paths do not have to be resubmitted for flight and safety analysis. By using a pre-approved flight path, range customers eliminate the 60 day requirement for submission. All of these mitigation procedures would allow for a single, reusable flight profile, reducing the pre-launch operations to something as simple as pulling an approved profile from the shelf.

2. Crew Readiness

Crews will have to be assigned and put on call for a set period of time to ensure availability and readiness. Leave for military members may need to be restricted to the local area. A period of one month minimizes the number of crews requiring readiness training each year without putting undue burden on the crew members. The on call period should begin with a range-only Mission Dress Rehearsal and a Range Readiness Review. Additional crew training and launch vehicle familiarization could be scheduled on a crew or individual basis as needed based on the MDR performance, ensuring all crew members are ready prior to mission identification. All crew force management activities could also be accomplished at the beginning of the on call period, ensuring all personnel are medically cleared and have met all recurring training and evaluation requirements for currency.

The ROC and OD/LDA Mission Plan is a labor intensive job aid required by the 30 SW. Both are developed by the ROC and approved by the 2 ROPS Director of Operations. In order to minimize extra work and streamline the development timeline, the

requirement to build an approved ORS Tier-2 Mission Plan should be included as part of the ROC Certification. This would allow for personalization by the operator with a nearly complete draft already on hand. Formatting and verbiage should be updated whenever a ROC is assigned as an on-call crewmember to incorporate changes and lessons learned from the most recent launches.

3. Documentation

The UDS system involves a series of administrative submittals and responses, ultimately resulting in the Operations Directive for a specific launch. Typically, commercial launches require a unique Launch OD due to the multitude of variables that affect commercial satellite launches. A Mission Specific OR is submitted, and from those requirements Section III is written and published. The WR has streamlined the OD process for ICBM launches due to the consistent nature of test launches. A similar strategy could be employed for a Tier-2 ORS launch. Specific information could be added by means of a VPS, a process already in use. This would allow the WR to pull the generic ORS OD Section III off the shelf and begin mission planning right away instead of having to rewrite the document every time.

Countdown manuals are typically due two weeks prior to first use. Similar to using an off the shelf OD, by keeping as many launch parameters the same as possible and by standardizing the payload checkout procedures, a single pre-approved range countdown manual could be used for ORS launches. Much like the ICBM countdown manual, very little would have to change between different ORS launches, and payload peculiarities could be addressed with change pages instead of writing a mission specific countdown manual. This has the added benefit of allowing military range personnel to train with the same countdown manual that would be used on day of launch, eliminating some of the risk and challenge of launching with seven days notice.

E. LIMITING FACTORS

There are a significant number of limiting factors that will impact the ability to meet an accelerated launch schedule. First, final launch vehicle preparation cannot occur for either vehicle until the payload has been integrated; the Minotaur I upper and lower

stacks are not integrated without the payload, and the Pegasus cannot be mated with the L-1011 without it. Payload integration and testing and fairing installation are not possible until after mission declaration when a payload is selected; as seen earlier, these are the two longest events in the launch timeline.

There is a certain level of uncertainty in instrumentation availability, which makes universal ORS Tier-2 launch documentation impossible. Depot level maintenance, age related failures, and other operational requirements can all influence a site's ability to support a launch. A VPS will be necessary for every ORS launch, specifying which instrumentation sites will be utilized. Frequency protection requirements may also change depending on what the ORS payload is, as well as what other vehicles and payloads are already in place on other launch pads. In addition to deconflicting frequencies, schedule deconfliction will also be necessary. Decision makers will have to prioritize between the ORS launch and launch-on-schedule operations that may be days away from launch, either delaying launch dates or finding innovative ways to share resources in a way that allows both operations to proceed.

Weather is an uncontrollable factor that will impact the ability to meet the seven day schedule. Hazardous operations like vehicle transportation and fueling can be delayed or scrubbed due to inclement weather, and launch operations cannot violate mandatory weather constraints. There is no way to mitigate the weather, but it must be considered as a limiting factor.

The Launch Readiness Review is required by AF Instructions, and is held one day prior to launch. This cannot be accomplished in advance, and does require a lot of work and preparation by key range personnel. The LRR is typically the last action prior to releasing all personnel for crew rest. Eight hours of crew rest is required for all range operators prior to arriving on console for launch countdown operations. Crew rest does not affect the range's ability to support L-1 checks, as those actions do not need to be accomplished by the launch team personnel, but it can prevent MDRs from being executed the day before launch depending on the scheduled launch window.

Launch crews include military, contractor, launch vehicle, and spacecraft personnel. Launch vehicle and spacecraft personnel are not all located at Vandenberg AFB, and sending individuals out there on a routine basis for green card dress rehearsals prior to mission identification is not cost efficient. For the first few Tier-2 ORS launches it will be essential for the launch crew to complete a full mission dress rehearsal. As crewmembers gain experience and Tier-2 launches become more routine, the requirement for multiple full scale rehearsals may be able to be waived.

Budget will be a critical factor in a Tier-2 ORS mission. The cost of maintaining a launch vehicle in standby mode will be significant, especially if the demand for launches is low. Additionally, the price of retaining the parts required to rapidly build an off-the-shelf satellite may also be cost prohibitive.

F. CURRENT STATE OF OPERATIONALLY RESPONSIVE SPACELIFT

1. Improving Spacelift Responsiveness

Several key assumptions were made while estimating the shortest possible launch schedules. In order to make those assumptions valid within an established launch-on-demand culture, a certain level of emphasis on improvements is needed. First and foremost, Tier-2 launch vehicles will need to be purchased in advance and prepositioned in a hot standby mode with all preparation activities up until payload integration already completed. This is a drastic change to the current space launch model in which vehicles do not begin launch preparation until after assignment to a payload mission occurs. Maintaining a vehicle in an ongoing state of readiness may present several challenges, including a need for increased launch vehicle personnel which may drive up costs for conventional launch-on-demand vehicles, vehicle issues that stem from waiting in a ready state for prolonged periods of time, and a potential increase of launch failures due to the time lapse between critical launch vehicle checkouts and day of launch. A potential risk mitigation option would be to allow or require Orbital to swap a Tier-2 vehicle with a launch-on-schedule vehicle in order to ensure the oldest vehicle launches first; while this reduces risk for Tier-2 launches, it arguably increases risk for conventional launches and

will likely only be permitted for low priority payloads that can accept the additional risk of a slightly older launch vehicle.

Authorizing around-the-clock operations will also be key to the seven day schedule. The current launch model relies on a single crew working standard eight hour days with overtime authorized when necessary. Tier-2 launches would require three full crews available. This will require Orbital to hire additional personnel, not only to man the three crews but to ensure that personnel preparing vehicles to launch other payloads or on other ranges are not pulled away, causing undesired delays to other launch programs. It may be necessary to have dedicated ORS personnel on contract and permanently stationed at Vandenberg for quick call up. WROCI will also need to hire additional site personnel to ensure that the range can support pre-launch instrumentation requirements outside of normal duty hours. Three full crews are probably not necessary for WROCI, however they may incur budget issues should overtime be necessary to support Tier-2 operations around the clock. In a budget constrained environment, this assumption may prove to be the biggest challenge for the seven day model.

Along with hiring more personnel, all involved agencies will have to make a concerted effort to focus on proficiency training. The rapid launch concept only works if delays due to lack of proficiency can be minimized if not avoided completely. Executing dry runs, dress rehearsals, and personnel readiness evaluations periodically regardless of whether a Tier-2 launch is imminent will be critical to ensuring all personnel are trained to the required level of proficiency when a launch actually occurs.

The final significant assumption is establishing a single standardized launch profile, or small selection of pre-approved launch profiles, in order to publish the OR and OD in advance, get an approved flight plan, and ensure that any Tier-2 payload can be interchanged with any Tier-2 launch vehicle. The final payload mass, vehicle mass, launch azimuth, flight path, and targeted transfer orbit will have to be identical for each mission using a specific launch profile to avoid having to repeat critical safety tasks. This will drastically impact how Tier-2 satellites are developed, but long term it will facilitate rapid launch. Failure to standardize Tier-2 missions will easily add an additional 30 days

to a launch schedule if each mission uses a unique profile instead of selecting the pre-approved profile that most closely matches the mission requirements.

In order to make this concept work, the AF or DoD will need to contract a single vehicle and a single range for Tier-2 launches. The requirements for maintaining different standby vehicles on multiple ranges are expensive and create logistical problems. There are pros and cons for both of the vehicles examined in this thesis; the Pegasus is closer to achieving the seven day schedule, however Orbital only operates a single L-1011, which may not be able to relocate to Vandenberg with a couple days notice without adversely impacting other Pegasus missions. The Minotaur is better suited for hot standby, but it will take more process and proficiency improvement to reduce the launch schedule. Selecting a single Tier-2 vehicle is critical to the success of the launch-on-demand model, both from a cost and a readiness perspective.

The simplest and most responsive solution would be to prepare launches for each type of payload and have them all set up on the launch pad awaiting final fueling and range checkout. While this would produce the shortest possible timeline, the cost of maintaining that many different payloads and their associated launch vehicles would be extremely prohibitive. Additionally, Vandenberg AFB currently only has a single launch pad designated for Minotaur I launches and there is only one L-1011 in operation. Building and maintaining additional launch pads and aircraft would further add to the cost of this method.

Several improvements to the range structure and operating concept could help shorten the Tier-2 launch schedule. Currently, the WROCC B side is not used. Dedicating the B side to be available for Tier-2 launch preparation would reduce the impact to the range schedule by allowing launch-on-demand operations to run simultaneously with pre-scheduled activities when resources weren't conflicting. It would be difficult to conduct two launches at the same time as there is only one Area Control Center, Mission Flight Control Center, and one Command Management Center, therefore those personnel would need to split attention between operations, but with a separate Mission Room for the A side and B side and identical A and B side consoles in the Range Control Center, pre-launch operations could be conducted at the same time as mission dress rehearsals,

launch operations, or other pre-launch activities with minimal impact. The limiting factor would be the availability of range instrumentation.

The AF will have to reevaluate the range downsizing activities if Tier-2 is going to be a launch priority. Redundant systems at Vandenberg and several WR support sites have been mothballed in the last ten years to reduce operating costs; in order to support multiple operations or site down time due to depot level maintenance, some of these sites may need to be re-commissioned and additional sites may need to be acquired to ensure the range can support a Tier-2 launch at any time. In addition to the challenges involved in the allocation of instrumentation when there are conflicting operations occurring, frequency management also increases in complexity with the addition of an unplanned launch. Frequency conflicts may force other launch customers to delay or cancel operations to prevent radiating a Tier-2 vehicle or payload on a sensitive frequency.

Operator readiness will be a challenge. It is not reasonable to dedicate personnel for Tier-2 launches or to increase the number of military operators on hand, however assigning a crew to be on call for a short duration ensures adequate time for specialized training and ramp up without delaying launch-on-demand activities or depriving personnel of launch experience during Tier-2 demand droughts. Crews could be assigned for a set period to ensure readiness and availability and to minimize the number of crews requiring readiness training each year without putting undue burden on crew members. A second option would be to use Air Force Reserve personnel for Tier-2 operations. Currently there are no reservist positions within 2 ROPS, but the addition of reservist billets could potentially reduce operator costs without sacrificing proficiency or launch experience. The on call period would optimally begin with a MDR and a RRR. In the event of mission declaration, the GRR could then be briefed on day one upon payload delivery, since the RRR will have already been accomplished. The briefing will change each month as crews and available instrumentation change, making it worthwhile to repeat the RRR with each new crew.

The ROC and OD/LDA Mission Plans are a very time and labor intensive set of job aids required by the 30 SW. Both are developed by the ROC and approved by squadron leadership. In order to minimize extra work and streamline the development

timeline, the requirement to build an approved Mission Plan could be included as part of the ROC certification process. Since Mission Plans are tailored to the individual, this would allow for personalization by the operator with a nearly complete draft ready prior to being assigned to the on call crew. Formatting and verbiage could be updated during recurring classroom training or upon crew assignment to incorporate changes and lessons learned from the most recent launches. These administrative changes to the way Mission Plans are written would reduce the development time from weeks to a matter of hours.

The final change necessary is to make ORS a higher priority. In the 2013 budget request, the Air Force proposed closing the ORS Office and instead allocating a small portion of the money saved to other military space programs to fund the integration of ORS into those programs. This strategy may work for ORS Tier-1 and Tier-3 launches, but would likely make Tier-2 unachievable any time in the near future. There needs to be a dedicated emphasis on changing the way the launch community does business in order to ensure it is able to keep up with the demand for increasing responsiveness of the satellite acquisition process. Without a single entity providing the necessary guidance and standardization between ORS programs, it is unlikely that the AF and DoD will be able to proceed with a launch-on-demand capability.

2. Concept Validation

The only guaranteed way to determine the feasibility of a seven day launch schedule is to exercise the concept. The Tac-Sat 2 launch was a good initial assessment of responsiveness, but future testing would need to go further, beginning with the establishment of a standardized ORS payload and launch profile.

The U.S. Air Force Academy astronautical engineering department produces experimental satellites, called FalconSat, as senior capstone projects. An ORS satellite would be an excellent application. The payload should be commercial off the shelf (COTS), with a standard bus, and a predetermined size and mass.

Certain pre-coordination events would have to be completed in advance. The UDS process would have to be completed for the “unknown” payload, based on a predetermined orbit, flight path, and payload mass. A launch vehicle would have to be

prepared in advance, but could be assigned an on call timeframe instead of a schedule launch date.

The program capstone would be delivery of FalconSat to VAFB, kicking off the seven day launch countdown. To sufficiently test the capability, all launch notifications and final preparations could not be accomplished until the payload arrived. The launch date would have to be pre-scheduled to ensure range availability, but a certain amount of restraint will have to be exercised by all involved to prevent war gaming and task accomplishment prior to the launch window. The budget will have to be designed to permit military, civilian, and contractor personnel to work shifts around the clock in order to launch on time. Subsequent FalconSat payloads could be designed and delivered meeting the ORS Tier-2 profile to allow for additional testing and exercising of the ORS concept.

Results from this sort of operational concept validation would provide valuable feedback to ORS planners, launch vehicle companies, and range personnel, and would pave the way for future launch-on-demand improvements and successes.

G. CHAPTER SUMMARY

As it currently stands, neither launch vehicle is capable of launching within seven days. However, various opportunities for improvements exist that could reduce the current estimates of eight days for the Pegasus and ten days for the Minotaur I down to the desired seven day schedule. Changes will be needed doctrinally, procedurally, and operationally in order to achieve this ambitious, yet feasible, schedule.

THIS PAGE INTENTIONALLY LEFT BLANK

V. CONCLUSIONS

A. KEY POINTS AND RECOMMENDATIONS

There are a variety of steps that must be taken in order to make spacelift more responsive in order to support the seven day launch schedule required to support a Tier-2 ORS mission. These interest items can be broken down into three categories; equipment, personnel, and administrative. All need to be addressed in order for the spacelift community to convert from a launch-on-schedule to a launch-on-demand culture.

1. Equipment

The DoD will need to select one launch vehicle to support ORS Tier-2 launches and dedicate training, funding, and focus on making that vehicle as responsive as possible. These Tier-2 vehicles would need to be prepositioned at the launch vehicle processing facility with all activities complete up to payload integration. A rotation would likely need to be established to swap out a stand-by vehicle with a new vehicle earmarked to support an on-schedule mission to ensure that the oldest launch vehicles always launch first in order to mitigate the risk of keeping vehicles in stand-by for long periods of time. ICBM launch failures, like the one that occurred 27 July 2011, indicate the risk associated with maintaining an aging fleet of standby launch vehicles (The Associated Press 2011, n.p.). Additionally, launch vehicle personnel will need to review and improve all processes and procedures in order to streamline vehicle preparation and further shorten the launch timeline. Currently both the Minotaur I and the Pegasus are outside of the seven day launch schedule objective, but the most effective way to reduce the time required will be procedurally. This may involve reordering the way a launch vehicle is prepared for launch in order to accomplish as many tasks prior to payload delivery as possible, which will reduce the overall timeline from an ORS perspective.

The AF will need to reevaluate the current range downsizing and mothballing of sensors that may be critical to ORS launch success. New processes may need to be developed to ensure that mothballed sites can be activated on short notice to support a Tier-2 launch or additional funds may need to be allocated to support additional

instrumentation sites. The utilization of the WROCC A and B sides may need to be addressed in order to maximize the number of operations the center can support simultaneously and thereby minimize the impact of ORS launch operations to existing launch-on-schedule operations.

2. Personnel

Funding will need to be allocated for dedicated ORS personnel on contract with the launch agency. This will eliminate conflict from launch-on-demand missions occurring at the same time and launch-on-schedule missions involving the same launch vehicle. Additionally, by hiring personnel whose primary responsibility is ORS Tier-2 launches, the opportunity exists to maximize training and efficiency of personnel for rapid launch missions well in advance of mission declaration.

Similarly, the AF will need to establish an on-call routine for ORS operators or create and staff reservist billets to supplement and/or fulfill on-call Tier-2 launch duties. This will allow sufficient time for specialized training and ramp up without delaying ORS activities or negatively impacting military range operators. By cycling through dedicated crews for set periods of time, range operations personnel will be able to accomplish relevant readiness reviews, develop mission plans, and complete range-only dress rehearsals without interfering with or delaying other launch operations.

Finally, the AF, launch agency, and contracted support personnel will need to be authorized to perform around the clock operations in support of Tier-2 launches. This will require increasing the number of personnel on contract to man three full crews on eight hour shifts, consistent with assumptions made during the TacSat-2 launch. Personnel costs may prove to be prohibitive; if so, workload distribution may need to be assessed in order to maximize the work that can be done by smaller crews or on longer work shifts.

3. Administrative

In order for Tier-2 spacelift responsiveness to be possible, ORS must become a DoD and AF priority. The AF ORS Office will likely be closed in 2013 due to budget cuts; some funding will need to be allocated and the office will need to remain open if the

DoD and AF intend to pursue responsive spacelift. Additional funds will need to be committed in order to procure vehicles and develop off-the-shelf standardized ORS payloads. This will require extensive reworking of the current budget to find the money to fund ORS.

AF doctrine and professional development programs will need to be reworked to emphasize responsive spacelift and operationally responsive space. This will ensure that decision makers are aware of ORS capabilities available to them, with particular focus needed on Combatant Commanders who will be the driving force behind Tier-2 mission requirements. Standardizing ORS payloads and launch profiles will help to increase the number of critical administrative tasks that can be accomplished prior to mission declaration. Additionally, doctrine must be written in a way that ensures the launch community is able to keep up with the increasing responsiveness of the satellite acquisition process. Educating senior leaders in all services on the options and potential of responsive payloads and launch vehicles will help ORS become a standard operating procedure.

B. AREAS TO CONDUCT FURTHER RESEARCH

A Capabilities and Limitations (C&L) Report serves to inform the warfighter and fielding decision authorities by presenting the potential operational effectiveness and suitability of a system from an unbiased Operational Test Agency, based on that system's capabilities and requirements documents. It provides an operational test perspective on the developmental capabilities and limitations based on existing testing and evaluation data (*Air Force Instruction 99-103* 2009, 49). Using all relevant historical launch data, a C&L Report could be compiled for all available launch vehicles launching from all available launch sites. This information would reveal far more detailed estimates for current launch capabilities than this thesis presented and would better identify processes that require streamlining in order to afford the flexibility and responsiveness needed to meet ORS objectives. By expanding the report to include all vehicles and all launch sites, it is possible that a more suitable and responsive launch vehicle exists that can meet the rapid launch requirements of a Tier-2 mission.

Additional missions like TacSat-2 are excellent opportunities for additional research into the potential for increasing the responsiveness of existing launch vehicles. Programs like FalconSat, the ORS satellite family, and TacSat can be used to put Tier-2 principles into practice and evaluate the launch community's ability to meet a rapid launch timeline. The only way to establish whether or not a seven day Tier-2 schedule is possible is to attempt it.

LIST OF REFERENCES

- 30th Space Wing Instruction 13–203*. 9 August 2011. Air Force E-Publishing. Accessed 2 September 2012. <http://static.e-publishing.af.mil/production/1/30sw/publication/30swi13-203/30swi13-203.pdf>.
- 30th Space Wing Instruction 91–101*. 30 July 2009. Air Force E-Publishing. Accessed 2 September 2012. <http://static.e-publishing.af.mil/production/1/30sw/publication/30swi91-101/30swi91-101.pdf>.
- 392d Training Squadron. “Spacelift Fundamentals.” *Technical Training*. Vandenberg AFB: Air Education and Training Command, October 2005.
- Air Force Doctrine Document 1*. 17 November 2003. Air Force E-Publishing. Accessed 9 January 2011. http://static.e-publishing.af.mil/production/1/af_cv/publication/afdd1/afdd1.pdf.
- Air Force Doctrine Document 2-2*. 23 August 1998. Air Force E-Publishing. Accessed 19 January 2011. http://static.e-publishing.af.mil/production/1/af_cv/publication/afdd2-2/afdd2-2.pdf.
- Air Force Instruction 10-1211*. 17 July 2006. Air Force E-Publishing. Accessed 14 July 2012. http://static.e-publishing.af.mil/production/1/af_a3_5/publication/afi10-1211/afi10-1211.pdf.
- Air Force Instruction 99-103*. 20 March 2009. Air Force E-Publishing. Accessed 22 September 2012. http://static.e-publishing.af.mil/production/1/af_te/publication/afi99-103/afi99-103.pdf.
- Air Force Policy Directive 10-12*. 1 February 1996. Air Force E-Publishing. Accessed 8 September 2012. http://static.e-publishing.af.mil/production/1/af_a3_5/publication/afpd10-12/afpd10-12.pdf.
- Air Force Space Command Instruction 10-1202*. 15 November 2008. Air Force E-Publishing. Accessed 14 July 2012. <http://static.e-publishing.af.mil/production/1/afspc/publication/afspci10-1202/afspci10-1202.pdf>.
- Air Force Space Command Instruction 10-1208*. 11 January 2011. Air Force E-Publishing. Accessed 2 June 2012. http://static.e-publishing.af.mil/production/1/af_a3_5/publication/afpd10-12/afpd10-12.pdf.
- Air Force Space Command Instruction 10-1213*. 24 August 2012. Air Force E-Publishing. Accessed 29 September 2012. <http://static.e-publishing.af.mil/production/1/afspc/publication/afspci10-1213/afspci10-1213.pdf>.

- Air Force Space Command Instruction 36-2202 Volume 1*. 1 January 2010. Air Force E-Publishing. Accessed 29 September 2012. <http://static.e-publishing.af.mil/production/1/afspc/publication/afspci36-2202v1/afspci36-2202v1.pdf>.
- Air Force Space Command Manual 91-710 Volume 1*. 1 July 2004. Air Force E-Publishing. Accessed 2 June 2012. <http://static.e-publishing.af.mil/production/1/afspc/publication/afspcman91-710v1/afspcman91-710v1.pdf>.
- Air Force Space Command Manual 91-710, Volume 2*. 1 July 2004. Air Force E-Publishing. Accessed 15 July 2012. <http://static.e-publishing.af.mil/production/1/afspc/publication/afspcman91-710v2/afspcman91-710v2.pdf>.
- Air Force Space Command Manual 91-711*. 1 February 2007. Air Force E-Publishing. Accessed 2 June 2012. <http://static.e-publishing.af.mil/production/1/afspc/publication/afspcman91-711/afspcman91-711.pdf>.
- Allard, Wayne and Bill Nelson. "Defense Space Activities: Continuation of Evolved Expendable Launch Vehicle Program's Progress to Date Subject to Some Uncertainty." 24 June 2004. *U.S Government Accountability Office*. Accessed 9 July 2012. <http://www.gao.gov/assets/100/92672.html>.
- Bauer, Thomas P. et al. "Systems Engineering for Responsive Launch." *4th Responsive Space Conference*. Los Angeles: AIAA, 2006. Accessed 9 July 2012. www.scorpius.com/Documents/RS4_Bauer.pdf.
- Brown, Kendall K. "A Concept of Operations and Technology Implications for Operationally Responsive Space." *Air & Space Power Journal* (2004). Accessed 9 June 2012. <http://www.airpower.maxwell.af.mil/airchronicles/cc/brown2.html>.
- Buccholz, Edward. "Minotaur I NROL-66 Program Support Manager Sheet." Vandenberg AFB, 1 February 2011.
- Buchholz, Edward. "Pegasus AIM Program Support Manager Sheet." Vandenberg AFB, 17 April 2007.
- Cooper, Lawrence A. "Assured Access to Space: The Dilemma of Reconstitution and Launch-On-Demand." *Airpower Journal* (1992). Accessed 9 June 2012. <http://www.airpower.au.af.mil/airchronicles/apj/apj92/sum92/cooper.htm>.
- Cooper, Lawrence. "The Strategy of Responsive Space: Assured Access to Space Revisited." *1st Responsive Space Conference*. Redondo Beach: AIAA, 2003. Accessed 30 May 2012. <http://www.responsivespace.com/Papers/RS1/SESSION1/COOPER/1003P.PDF>.
- Day, Dwayne. *Vandenberg Air Force Base*. Accessed 9 October 2012. <http://centennialofflight.gov/essay/SPACEFLIGHT/VAFB/SP47.htm>.

- Department of Defense Directive 3200.11*. 27 December 2007. Defense Technical Information Center. Accessed 12 June 2012. <http://www.dtic.mil/whs/directives/corres/pdf/320011p.pdf>.
- Department of Defense Directive 3200.11-D*. June 1983. Law, Science & Public Health Program Site. Accessed 11 June 2012. http://biotech.law.lsu.edu/blaw/dodd/corres/pdf/320011d_0683/p320011d.pdf.
- Everett, Terry. *Space Acquisitions: DoD Needs a Departmentwide Strategy for Pursuing Low-Cost, Responsive Tactical Space Capabilities*. GAO-06-449. Washington, DC: United States Government Accountability Office, 2006. Accessed 9 June 2012. <http://www.gao.gov/assets/250/249261.pdf>.
- Foust, Jeff. *Operationally Responsive Spacelift: A solution seeking a problem?* 13 October 2003. Accessed 18 March 2010. <http://www.thespacereview.com/article/52/1>.
- Graham, William. *Orbital Minotaur I launches with ORS-I following eventful countdown*. 29 June 2011. Accessed 23 April 2012. <http://www.nasaspaceflight.com/2011/06/live-orbital-minotaur-i-launch-ors-1/>.
- HQ AFSPC/DRS. *Mission Needs Statement AFSPC 001-01 for Operationally Responsive Spacelift*. Peterson AFB: USAF, 2001. Accessed 30 May 2011. http://www.smad.com/ORS%20MNS%20_Final%20Dec01_.pdf.
- Kennedy Media Gallery*. Ed. Jeanne Ryba. 6 March 2009. Accessed 15 June 2012. <http://mediaarchive.ksc.nasa.gov/search.cfm?cat=117>.
- Kim, Yool and Gary McLeod. "Toward a New Strategy for ORS." *High Frontier* vol. 6, no.3 (2010): 88-93. Accessed 9 June 2012. <http://www.afspc.af.mil/shared/media/document/AFD-101019-072.pdf>.
- King, Ledyard. *Report Warns of Weather Satellites 'Rapid Decline'*. 2 May 2012. Accessed 8 May 2012. <http://usatoday30.usatoday.com/weather/news/story/2012-05-02/weather-satellites-forecast-storms/54708804/1>.
- Kneller, Edward W. "National Security Space Office Responsive Space Operations Architecture Study." *4th Responsive Space Conference*. Los Angeles: AIAA, 2006. Accessed 16 June 2012. http://www.responsivespace.com/Papers/RS4/Papers/RS4_1003P_Kneller.pdf.
- Kolodziejski, Paul J. "Operationally Responsive Spacelift for the U.S. Air Force." *1st Responsive Space Conference*. Redondo Beach: AIAA, 2003. Accessed 16 June 2012. <http://www.responsivespace.com/Papers/RS1/SESSION1/KOLODZIE/1002P.PDF>.

- Ledbetter, Titus. *ORS Office Presses Ahead with Plans Despite Looming Closure*. 7 May 2012. Accessed 9 July 2012. <http://www.spacenews.com/article/ors-office-presses-ahead-plans-despite-looming-closure>.
- “Minotaur I Fact Sheet.” 2012. *Orbital Sciences Corporation*. Accessed 2 June 2012. http://www.orbital.com/NewsInfo/Publications/Minotaur_I_Fact.pdf.
- “Minotaur I User’s Guide.” January 2006. *Orbital Sciences Corporation*. Accessed 2 June 2012. http://www.orbital.com/NewsInfo/Publications/Minotaur_Guide.pdf.
- Moskios, Thomas. “Risk Analysis Report for the Tac-Sat 2 Mission.” 17 November 2006. NASA. Accessed 5 June 2012. http://code210.gsfc.nasa.gov/nsoc/Tac%20Sat%20_WFF_RAR.pdf.
- NASA Policy Directive 8610.7D. 31 January 2008. NASA. Accessed 4 July 2012. http://nodis3.gsfc.nasa.gov/npg_img/N_PD_8610_007D_/N_PD_8610_007D__main.pdf.
- National Research Council. *Streamlining Space Launch Range Safety*. Washington, DC: National Academy Press, 2000.
- National Security Space Office. “Plan for Operationally Responsive Space - A Report to Congressional Defense Committees.” 17 April 2007. *Responsive Space*. Accessed 19 January 2011. <http://www.responsivespace.com/Conferences/RS5/4=17=07%20ORS%20Plan.pdf>.
- Noel, Jeremy, Raymond Escorpizo and Edward Jones. “Transforming the National Spacelift Architecture.” *2nd Responsive Space Conference*. Los Angeles: AIAA, 2004. Accessed 27 May 2012. <http://www.responsivespace.com/Papers/RS2/SESSION%20PAPERS/SESSION%202/NOEL/2003P.pdf>.
- O’Connor, Bryan. “NASA Range Safety Annual Report.” 2010. NASA. Accessed 27 May 2012. http://kscsma.ksc.nasa.gov/Range_Safety/Annual_Report/2010/Documents/2010_NASA_RANGE_SAFETY_ANNUAL_REPORT.pdf.
- Operationally Responsive Spacelift Initiative*. 21 July 2011. Accessed 24 March 2012. <http://www.globalsecurity.org/space/systems/ors.htm>.
- Orbital Sciences Corporation*. 2012. Accessed 12 May 2012. <http://www.orbital.com/>.
- “Pegasus User’s Guide.” June 2007. *Orbital Sciences Corporation*. Accessed 2 June 2012. http://www.orbital.com/NewsInfo/Publications/pegasus_ug.pdf.
- Pieczynski, Mark. “Operationally Responsive Space from a Launch Vehicle Perspective.” *High Frontier* vol. 6, no. 3 (2010): 94–95. Accessed 26 May 2012. <http://www.afspc.af.mil/shared/media/document/AFD-101019-072.pdf>.

- Range Commander's Council*. 22 May 2012. Accessed 22 May 2012.
<http://www.wsmr.army.mil/RCCsite/Pages/default.aspx>.
- Range Commanders Council Document 319–10*. 4 August 2010. White Sands Missile Range. Accessed 14 July 2012. [https://wsmrc2vger.wsmr.army.mil/rcc/manuals/319-10/319-10%20Flight%20Termination%20Systems%20Commonality%20Standard%20\(Public%20Release\).pdf](https://wsmrc2vger.wsmr.army.mil/rcc/manuals/319-10/319-10%20Flight%20Termination%20Systems%20Commonality%20Standard%20(Public%20Release).pdf).
- “Range Safety Operations Requirements.” Vandenberg AFB: 30th SW Safety, 2 November 2007.
- Remillard, Stephen K. “The Long and Winding Road to Operationally Responsive Spacelift.” *Air & Space Power Journal* (2007) Accessed 27 May 2012.
<http://www.airpower.maxwell.af.mil/airchronicles/apj/apj07/spr07/remillardspr07.html>.
- Roth, John. “Benefits of Returning to the Original Vision of Operationally Responsive Space.” *High Frontier* vol. 6, no. 3 (2010): 83–87. Accessed 27 May 2012.
<http://www.afspc.af.mil/shared/media/document/AFD-101019-072.pdf>.
- Schoneman, Scott et al. “Minotaur I Demonstration of Responsive Launch for the TacSat-2 Mission.” *5th Responsive Space Conference*. Los Angeles: AIAA, 2007. Accessed 4 July 2012. http://www.responsivespace.com/Papers/RS5/SESSION%20PAPERS/SESSION%205/5002_SCHONEMAN/5002P.pdf.
- Seo, David. “Responsive Range Operations.” *4th Responsive Space Conference*. Los Angeles: AIAA, 2006. Accessed 27 May 2012. http://www.responsivespace.com/Papers/RS4/Papers/RS4_2005P_Seo.pdf.
- “Space Launch Sample Mission 1 Mission Requirements Document.” 18 May 2011. *Cryptocomb*. Accessed 14 July 2012. [http://cryptocomb.org/MRD1_\(JMAPS\)_v2.pdf](http://cryptocomb.org/MRD1_(JMAPS)_v2.pdf).
- The Associated Press. *ICBM destroyed during launch for safety reasons*. 27 July 2011. Accessed 13 January 2013. <http://www.armytimes.com/article/20110727/NEWS/107270323/ICBM-destroyed-during-launch-safety-reasons>.
- Tomme, Edward B. “The Myth of the Tactical Satellite.” *Air & Space Power Journal* (2006). Accessed 14 January 2013. <http://www.airpower.maxwell.af.mil/airchronicles/apj/apj06/sum06/tomme.html>.
- Underwood, Bruce E., Steven E. Kremer and Wayne Woodhams. “NASA’s Wallops Flight Facility Rapid Responsive Range Operations Initiative.” *2nd Responsive Space Conference*. Los Angeles: AIAA, 2004. Accessed 9 July 2012.
<http://www.responsivespace.com/Papers/RS2/SESSION%20PAPERS/SESSION%204/UNDERWOOD/4006P.pdf>

U.S. Government Accountability Office. "DoD Needs to Further Clarify the Operationally Responsive Space Concept." July 2008. Accessed 24 March 2010. <http://www.gao.gov/assets/280/278188.html>.

Vandenberg Air Force Base - Home. 2012. Accessed 4 October 2012. [http:// www.vandenberg.af.mil/](http://www.vandenberg.af.mil/).

Wade, Mark. *Encyclopedia Astronautica Tacsat-2*. 16 December 2006. Accessed 8 September 2012. <http://www.astronautix.com/craft/tacsat2.htm>.

Wertz, James R. and Wiley J. Larson, *Space Mission Analysis and Design*. 3rd. El Segundo: Microcosm Press, 2003.

"Western Range User Handbook." Vandenberg AFB: 2d Range Operations Squadron, March 2009.

INITIAL DISTRIBUTION LIST

1. Defense Technical Information Center
Ft. Belvoir, Virginia
2. Dudley Knox Library
Naval Postgraduate School
Monterey, California